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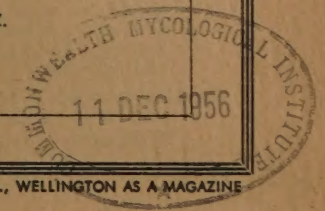

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NOTICES

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THE COPPER AND MOLYBDENUM CONTENTS OF PASTURES GROWN ON THE DIFFERENT SOILS OF NEW ZEALAND

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(Received for publication, 15 June 1956)

Summary

The writers consider that results from analysis for copper and molybdenum of a small number of pasture samples taken on representative areas of a soil type will give an indication of the copper and molybdenum for pastures over the whole area covered by that soil type.

This principle is applied to the consideration of results from 900 pasture samples collected in the spring from 280 soils in the North and South Islands of New Zealand.

Using as criteria less than 5 p.p.m. copper as deficient, and 3 p.p.m. molybdenum or more as too high, it was found that relatively small areas in both islands are deficient in copper and that in the North Island large areas totalling about 5 million acres and somewhat smaller areas in the South Island produce pastures with above-normal amounts of molybdenum.

These results are discussed in their application to agricultural advisory work on stock health and on the use of molybdate fertilizers.

INTRODUCTION

In New Zealand, as in other countries, too much dietary molybdenum has been found to have toxic effects on cattle[1]. Such toxicity is of current practical importance in this country as there are considerable areas of land which grow pasture containing harmful amounts of molybdenum. It is desirable to define these areas as accurately as possible so that corrective measures can be applied or recommended in advisory work on stock health.

There are other areas where the pasture molybdenum is high though not at toxic levels. It is important that these areas also should be defined, as molybdenum topdressing might increase the molybdenum level to a toxic one.

Again the copper in diet has an important influence on molybdenum toxicity—when the copper is low animals are susceptible to lower levels

of molybdenum intake and conversely increased dietary copper has a protective effect. It is desirable therefore that information on copper content should accompany that on molybdenum content of pasture.

This paper gives the copper and molybdenum contents of approximately 900 pasture samples collected over the North and South Islands in the spring months of 1953 and 1954. The purpose was to obtain as wide a cover of the Dominion as possible, showing areas of pasture high in molybdenum or low in copper, and it was obviously desirable that the results of the analytical work should be applicable to a vastly greater area than that actually sampled. To give this "area" to the results the soil map was adopted as the basis for sampling, and each pasture sample was collected from an identified soil. The results tabulated and discussed below cover pastures grown on practically all the pasture-producing soils of New Zealand.

Experimental

Sampling

To ensure definite identification of each soil from which pasture samples were collected, assistance was sought from the Soil Bureau, Department of Scientific and Industrial Research, and a pedologist from that Bureau accompanied one of the authors on every sampling trip.

Where possible, at least three samples were taken from widely separated locations on each soil. All were analysed as separate samples.

The pasture sample was collected by clipping randomly selected areas, 20 yards or more apart, and usually located on a uniform area several acres in extent though on steep hillsides this procedure had sometimes to be modified. About two pounds of green grass was collected and forwarded without delay to the laboratory, where the sample was quickly dried in a current of warm air, finely ground and bottled. Though notes were taken of the botanical composition of the sward no attempt was made to separate the different components.

Spring growth of pasture was sampled and this meant a collection period from about mid-September to mid-October in northern districts and between mid-October and end of November in southern districts. In most cases the cattle pastures sampled were about 6 inches high and sheep pastures about 1 to 2 inches high.

Analytical methods

Copper was determined by the method of Clare, Cunningham and Perrin[2], and molybdenum by Perrin's method[3].

The results are expressed as parts per million (p.p.m.) in the dry grass.

Area of soil

For each of the North Island soils an approximate area is shown. This area was computed from dissecting a 4-mile-to-one-inch soil map[4], weighing the parts and converting the weights to area by appropriate calculation. This method is admittedly approximate but provides a guide to the area covered by the soil.

Results

The results are presented in Tables 1, 2, and 3; Table 1 contains the copper-deficient soils, Table 2 the high-molybdenum soils, and Table 3 the normal soils.

Each table includes North Island and South Island samples and the samples from each Island are grouped together. For the North Island samples the first two columns show the soil set by name and number, quoted from *N.Z. Soil Bureau Bulletin 5*[1], and arranged in numerical order of soil numbers. Where a name is added in brackets this refers to a particular soil of the set, recognized in more detailed surveys and either described or to be described in other soil bulletins. Information on the geographical location of these soils can be obtained from maps which accompany the soil bulletins.

For the South Island samples the first column shows the soil names which are those used by the Soil Bureau at the date of publication of this paper. The 4-mile-to-the-inch map covering the whole of the South Island has not yet been published, though preliminary maps have been prepared and are with Agriculture Instructors.

Subsequent columns for both North and South Islands show the number of pasture samples collected from each soil, the number below 5 p.p.m. copper and 3 p.p.m. molybdenum (Table 1), or 3 p.p.m.

TABLE 1. SOILS WHICH GROW PASTURE LOW IN COPPER CONTENT. COPPER BELOW 5 P.P.M., MOLYBDENUM BELOW 3 P.P.M.

NORTH ISLAND†

Soils†	Soil No.†	No. of Samples	No. below 5 p.p.m. Cu	Average		Range		Area 000 acres
				Cu	Mo	Cu	Mo	
Marsden sand	23c	1	1	4.3	1.4			3.0
Purimu silt loam, hill soils	31dH	1	1	4.8	<1.0			18.4
Te Kopuru sand	47d	7	7	3.2	1.3	1.1–4.9	<1.0–2.0	93.2
Whakatane gravelly sandy loam	51	2	1	4.9	2.5	3.2–6.6	2.2–2.9	40.3
Pukeokahu silt loam	113b	1	1	4.5	2.5			5.5
							TOTAL	160.4

SOUTH ISLAND*

Cheviot silt loam		1	1	2.8	<1.0			
Glasnevin shallow sandy loam		5	2	4.8	<1.0	2.5–5.9	<1.0–<1.0	
(Moutere)* clay formation		2	2	4.4	<1.0	4.3–4.5	<1.0–<1.0	
Otanomomo peat		1	1	3.7	<1.0			

† For North Island samples the soil names and numbers are those quoted in Soil Bureau Bulletin No. 5. Names in brackets following name of the soil, for North Island, are soils recognised in more detailed surveys.

* Soil names for the South Island general survey are provisional and in some cases may be altered when the survey is published (.....) indicates that a name has not been allotted and in such cases the texture is given and the district of origin shown in brackets after the texture. Names bracketed as (Moutere) indicates district but name not definitely allotted to soil.

TABLE 2. SOILS WHICH GROW PASTURE HIGH IN MOLYBDENUM CONTENT MOLYBDENUM ABOVE 3 P.P.M.

NORTH ISLAND†

Soils†	Soil No.†	No. of Samples	No. above 3 p.p.m.	Average		Range		Area 000 Acres
				Cu	Mo	Cu	Mo	
Manawatu set	1	25	6	8.9	2.4	6.6–11.3	<1.0–5.8	581.3
Tukituki set	1c	5	5	10.4	5.2	9.9–10.8	3.7–7.2	92.5
Kairanga set	2	16	6	10.2	3.0	7.8–13.1	<1.0–7.3	453.4
Opiki complex	2b	3	3	11.8	5.5	9.9–13.6	3.2–8.2	17.1
Rotomahana sandy loam	3	6	6	8.0	6.5	4.1–11.0	3.9–8.5	4.4
Otakiri gravel: well-drained phase	5a	2	1	4.8	2.7	3.9–4.6	1.4–3.9	.9
Otakiri complex	5c	2	2	10.0	3.4	9.4–10.6	3.2–3.6	.9
Konoti clay loam, hill soils	7bH	4	4	8.5	5.7	6.2–10.1	3.7–6.4	23.1
Matapiro silt loam**	8	4	3	7.0	4.8	5.4–9.2	1.4–6.8	41.0
Matapiro silt loam, hill soils**	8H	1	1	7.4	4.6			15.2
Manawahe gravel	14d	3	2	7.4	3.2	6.6–8.1	2.2–3.8	8.4
Awakeri complex	15b	9	4	10.3	2.6	8.4–12.7	1.4–3.5	3.6
Taupo set (Tuai coarse sand)	18	8	8	8.2	8.3	5.2–11.2	4.6–11.4	75.0
Taupo set (Tuai coarse sand, hill soils)	18H	5	5	7.7	7.3	6.8–8.9	4.5–11.1	125.0
Taupo set (Tuai shallow sand)	18a	9	4	6.9	3.1	4.7–9.0	1.7–5.0	26.0
Taupo set (Tihoi sand)	18b	4	4	5.1	4.6	4.2–6.3	3.4–7.5	36.0
Taupo set (Tihoi-Opa complex)	18b	3	3	7.1	6.1	6.2–8.0	4.0–7.4	
Rangipo sand	18e	8	2	10.8	1.6	7.1–14.6	<1.0–3.4	57.5
Taupo set (Marumaru coarse sand)	18g	9	3	8.0	5.5	7.1–9.1	2.1–15.9	10.0
Ngaroma set, unamed type, Taumarunui district	19	2	2	9.7	6.7	9.4–9.9	5.9–7.4	
Ngaroma sandy silt	19	8	2	9.9	3.0	8.4–13.0	1.5–7.1	176.5
Ngaroma sandy silt, hill soils	19H	3	1	9.7	3.8	7.2–11.6	1.7–6.9	339.0
Taumarunui sandy silt, hill soils	19aH	2	2	10.7	8.0	10.5–10.8	7.0–8.9	7.8
Manunui sandy silt	19d	3	1	10.1	2.3	9.1–11.3	1.8–3.1	26.5
Mamaku sandy silt	20	2	2	7.9	3.4	7.1–8.7	3.4–3.4	81.3
Gisborne sandy loam	21	9	1	7.6	1.9	5.9–11.9	1.2–3.4	82.4
Gisborne sandy loam, hill soils	21H	7	4	6.5	4.4	5.7–7.0	1.3–8.2	58.0
Matawai sandy loam	22	5	5	9.5	8.3	8.3–11.2	5.0–11.9	18.6
Kourarau silt loam	25c	4	1	9.7	2.0	7.0–13.0	<1.0–3.7	2.6
Wairama clay loam	26	1	1	11.8	6.7			8.8
Wairama clay, hill soils	26aH	3	2	10.7	3.9	9.6–11.5	2.0–5.5	11.0
Tutira sandy loam	49a	7	4	8.3	3.8	6.7–11.0	<1.0–6.2	21.6
Tutira sandy loam, hill soils	49aH	1	1	7.3	5.7			52.3
Whakatane gravelly sand	51a	7	2	7.8	2.0	5.4–9.0	<1.0–3.0	3.0
Whangamata gravelly sandy loam	53	2	1	13.4	2.7	13.1–13.6	2.3–3.0	3.6
Waipu clay	101d	3	1	9.0	2.8	7.2–10.9	<1.0–5.2	32.3
Otanga peaty loam	107b	11	3	6.6	2.2	3.9–10.2	<1.0–5.3	13.2
Ruakaka set	108b, 109	2	1	5.1	3.2	1.7–8.5	2.6–3.8	3.0 36.7
One Tree Point peaty sand	109b	3	1	6.1	2.6	1.7–10.9	1.3–3.8	9.7
Meeanee-Farndon complex	111	2	1	9.6	3.9	9.5–9.7	2.9–4.8	23.2
Takahiwai set	111c	1	1	8.6	9.2			13.8
Ahuriri set	112	3	3	8.0	7.9	6.0–11.2	5.0–11.3	5.7
Ahuriri set	112a	1	1	9.1	6.7			1.3
Ahuriri stony sand	112b	1	1	6.0	6.5			.6

(Table 2 continued)

Soils†	Soil No.†	No. of Samples	No. above 3 p.p.m.	Average		Range		Area 000 acres
				Cu	Mo	Cu	Mo	
Taihape silt loam	114a	18	7	7.5	2.9	4.4–10.8	<1.0–7.1	644.5
Turakina silt loam	114b	11	7	8.3	3.3	5.5–9.6	<1.0–7.0	88.2
Waitaha sandy loam	114c	7	1	8.2	2.6	6.4–11.4	2.0–4.0	80.9
Mahoenui silt loam	115	15	8	7.8	3.4	4.7–14.0	<1.0–8.9	444.6
Pahiatua silt loam	115a	7	1	7.4	1.8	5.9–8.7	<1.0–3.5	73.3
Hangaroa sandy loam	115b	14	6	7.7	3.7	5.7–10.9	<1.0–10.7	189.8
Waihua stony sandy loam	117d	3	3	7.9	8.7	6.1–9.2	5.4–13.0	77.7
Unidentified peat soils from farms where peat scours occur				6.9	11.7	1.7–10.2	4.5–16.5	
							TOTAL	4203.3
SOUTH ISLAND*								
Fairhall silt loam		3	1	6.0	1.4	3.7–7.9	<1.0–3.1	
Harihari fine sandy loam		1	1	12.3	5.3			
Harihari fine sandy loam (brown)		2	—	11.5	1.1	11.3–11.7	<1.0–1.7	
Harihari fine sandy loam (blue)		2	2	11.1	4.2	10.7–11.5	3.9–4.5	
Huihui sandy loam		3	2	5.4	2.4	4.1–6.3	<1.0–3.5	
Kini peaty loam		1	1	9.0	3.8			
Motukarara sandy loam, weakly saline phase		4	2	7.0	3.0	5.7–9.0	1.2–5.1	
Omihi silt loam		3	3	6.3	4.4	4.3–7.3	3.2–6.2	
Taitapu silt loam		4	1	9.5	1.3	7.6–10.4	<1.0–3.5	
Waikakahi complex silt loam		5	3	9.4	4.6	7.1–12.3	<1.0–7.5	
Waitapeka peaty silt loam		4	1	10.0	2.6	9.6–10.7	1.6–4.5	
Weka sandy loam		1	1	3.9	4.5			
Weka sandy loam (.....)* (terrace soils associated with Onepunga soils		14‡	13	7.0	4.9	5.6–9.9	2.6–7.5	
		15‡	10	4.7	3.9	3.2–5.7	<1.0–6.8	

† (See footnotes to Table 1)

* ** Pastures from these soils on one farm in Valley Road district, Hastings, have a much higher molybdenum content than the same series in other districts, though no physical differences in soils have so far been detected by soil surveys.

‡ From 1 farm only. Samples collected in all seasons of year.

molybdenum and higher (Table 2), or above 5 p.p.m. copper and below 3 p.p.m. molybdenum (Table 3): the average copper and molybdenum from all pastures from each soil, and the range in variation of copper and molybdenum for pastures from each soil.

In drawing up the tables, pastures with less than 5 p.p.m. copper were classified as deficient in copper and those containing 3 p.p.m. or more of molybdenum as above normal in molybdenum content.

Table 1

This lists pastures which contain less than 5 p.p.m. copper and less than 3 p.p.m. molybdenum, and thus shows the soils on which copper

TABLE 3. SOILS WHICH GROW PASTURES NORMAL IN COPPER AND MOLYBDENUM CONTENTS COPPER ABOVE 5 P.P.M., MOLYBDENUM BELOW 3 P.P.M.

NORTH ISLAND†

Soils†	Soil No.†	No. of Samples	No. 5 p.p.m. & above	Average		Range		Area 000 Acres
				Cu	Mo	Cu	Mo	
Waipunga set	1a	1	1	10.3	<1.0			17.4
Esk sand	1b	2	2	8.4	1.4	8.3–8.4	1.1–1.6	73.4
Tarawera gravel	5	9	7	6.6	2.2	3.7–9.0	1.3–2.9	63.5
Otakiri gravel	5a	2	2	8.4	<1.0	6.6–9.9	<1.0–1.2	.9
Otakiri gravel, deep phase	5b	1	1	7.7	2.2			14.5
Konoti clay loam	7b	1	1	9.1	<1.0			18.6
Dairy Flat set	7c	2	2	9.1	<1.0	8.4–9.7	<1.0–1.1	11.9
Matapiro silt loam	8	1	1	7.2	<1.0			41.0
Okawa sandy loam	8a	1	1	8.2	1.1			20.0
Matapiro silt loam, hill soils	8H	4	4	7.9	<1.0	5.8–7.7	<1.0–1.5	15.2
Matapiro sandy loam	9	1	1	7.8	1.2			71.8
Matapiro complex	9a	1	1	5.3	<1.0			16.2
Matapiro set (Crownthorpe sandy loam)	9H	3	3	8.3	<1.0	7.2–9.3	<1.0–1.3	25.5
Rissington sandy loam, hill soils	11cH	1	1	7.6	2.1			22.2
Ohakea loam	12	3	3	8.7	1.2	7.3–9.6	<1.0–2.0	58.3
Tokomaru silt loam	13	2	2	10.9	<1.0	10.8–10.9	<1.0–1.2	57.7
Milson silt loam	13a	2	2	9.2	<1.0	9.1–9.3	<1.0–<1.0	30.7
Halcombe silt loam	13b	3	3	7.5	<1.0	5.9–9.1	<1.0–<1.0	96.0
Halcombe silt loam, hill soils	13bH	1	1	6.1	<1.0			30.0
Marton loam	13c	4	4	7.6	<1.0	7.5–7.7	<1.0–<1.0	118.6
Kokotau silt loam	13d	1	1	5.8	<1.0			11.2
Paengaroa sand	14	2	2	6.4	1.7	6.3–6.5	<1.0–2.8	9.9
Ohinepanea sand	14c	2	2	7.3	1.6	6.6–7.9	<1.0–2.2	15.2
Awakeri gravelly sand	15	3	3	8.4	1.5	5.7–9.8	<1.0–2.0	5.4
Awakeri set	15	2	1	4.9	<1.0	4.0–5.8	<1.0–1.0	
Oropi sand	16	3	3	10.7	1.7	10.3–11.3	1.2–2.1	13.6
Kaharoa sand	17	3	3	9.5	<1.0	7.2–11.4	<1.0–1.6	43.9
Taupo sandy silt	18	10	8	6.1	<1.0	3.9–8.9	<1.0–2.0	79.8
Taupo shallow sandy silt	18a	7	7	8.3	1.5	6.0–10.1	<1.0–1.9	65.1
Taupo light sandy loam	18g	1	1	7.3	1.6			30.2
Maraeroa set	19b	3	3	9.2	1.6	7.4–11.1	1.2–2.1	28.6
Owhango sandy silt	19c	2	2	10.3	2.4	9.3–11.2	2.2–2.6	7.4
Mohaka sandy loam	21a	4	3	6.8	2.1	3.1–11.0	1.8–2.8	29.1
Patea sand	23	19	18	6.3	1.3	3.6–10.4	<1.0–2.7	130.1
Patea set (Himatangi sand)	23	2	2	9.1	<1.0	8.1–10.0	<1.0–<1.0	
Whananaki sand	23b	17	15	8.3	1.2	4.1–12.0	<1.0–2.8	92.4
Whananaki set (Pukepuke brown sandy loam)	23b	1	1	10.0	<1.0			
Red Hill set	24a	8	8	9.8	<1.0	5.3–14.2	<1.0–1.2	62.5
Horea set	24d	8	8	11.2	<1.0	9.0–14.6	<1.0–1.4	1.7
Horea set, hill soils	24dH	1	1	8.0	<1.0			18.9
Wairama clay	26a	1	1	11.2	2.1			1.5
Pakarae sandy loam	29c	1	1	11.7	1.4			5.4
Pakarae sandy loam, hill soils	29cH	3	3	10.7	1.7	8.5–13.3	1.3–2.1	137.8
Pakarae complex, hill soils	29dH	1	1	8.9	2.5			36.7
Taumata clay loam	31	2	2	8.1	<1.0	6.7–9.4	<1.0–<1.0	8.6
Waiotira light clay	31c	1	1	8.8	<1.0			11.8
Whareora clay loam	34d	1	1	8.6	<1.0			3.0
Marua clay loam	35	1	1	9.2	1.2			42.6
Marua clay loam, hill soils	35H	3	3	8.5	<1.0	7.4–10.5	<1.0–1.3	290.0
Ngaio set (Judgeford silt loam)	35b	1	1	7.7	<1.0			7.5

(Table 3 continued)

Soils†	Soil No.†	No. of Samples	No. 5 p.p.m & above	Average		Range		Area 000 Acres
				Cu	Mo	Cu	Mo	
Maungarei clay loam	36	1	1	5.2	<1.0			.9
Mata clay	40	1	1	8.1	<1.0			31.6
Rangiora clay loam	41	1	1	7.9	<1.0			18.3
Rangiora clay loam, hill soils	41H	1	1	11.0	1.5			105.0
Riponui sandy clay loam	44b	1	1	7.5	<1.0			10.2
Tauwhare set (Tauwhare sandy loam, hill soils)	44eH	1	1	7.2	<1.0			21.2
Waikare clay	45	1	1	12.5	<1.0			162.0
Waikare set (Otangaroa complex)	45	1	1	7.6	<1.0			
Waikare clay, hill soils	45H	1	1	6.1	<1.0			29.7
Hukerenui silt loam	46b	1	1	8.4	<1.0			65.3
Wharekohe silt loam	47	20	19	8.2	<1.0	4.5–11.3	<1.0–2.4	61.0
Te Kopuru set (Kaikino sand)	47e	1	1	8.7	<1.0			23.5
Mahia fine sandy loam	49b	2	2	11.3	1.8	10.7–11.8	<1.0–2.9	19.6
Katikati sandy loam	54	3	3	11.2	1.7	8.8–12.6	1.5–1.8	10.4
Waitekauri sandy loam	55	2	2	9.6	2.1	9.2–10.0	1.8–2.3	11.7
Tirau sandy loam	57	3	3	11.4	1.6	10.4–12.4	1.5–1.8	85.4
Ohaupo silt loam	59	2	2	12.6	1.5	12.5–12.7	1.2–1.7	53.7
Maihiihi silt loam	59c	3	3	10.3	1.5	5.8–14.0	<1.0–2.3	28.4
Dunmore silt loam	61, 61a	6	6	10.3	1.4	9.0–12.2	<1.0–2.7	38.6
Te Auku set	61c	3	3	9.2	<1.0	8.0–9.8	<1.0–<1.0	1.5
Kauroa silt loam	62b	3	3	11.7	1.5	11.4–12.2	<1.0–2.0	13.0
Mairoa silt loam	63	3	3	10.2	1.5	9.4–11.0	1.1–1.8	21.8
Ohakune silt loam	65	4	4	10.5	1.4	8.5–12.8	<1.0–1.9	42.9
Ohakune silt loam, hill soils	65H	1	1	6.9	<1.0			38.0
Egmont black loam	66a	2	2	12.9	1.3	12.0–13.8	<1.0–2.1	139.3
Westmere silt loam	66d	1	1	9.0	<1.0			29.1
New Plymouth brown loam	67	1	1	7.6	<1.0			42.2
New Plymouth sandy loam	67b	1	1	8.9	<1.0			30.9
New Plymouth sandy loam, hill soils	67bH	1	1	6.5	<1.0			49.7
Stratford sand	68	3	3	12.1	1.2	6.9–16.6	<1.0–1.7	87.7
Kiwitea set (Belmont silt loam)	76a	2	2	7.0	<1.0	6.3–7.7	<1.0–<1.0	102.4
Kiwitea loam	76a	2	2	10.0	<1.0	9.9–10.1	<1.0–1.3	
Kiwitea loam, hill soils	76aH	1	1	14.3	<1.0			55.5
Kawhatau stony silt loam	76b	1	1	7.1	<1.0			23.9
Hamilton clay loam	83	2	2	11.3	<1.0	10.8–11.8	<1.0–<1.0	126.3
Opuatia set	83c	4	4	10.9	<1.0	8.9–12.4	<1.0–1.4	11.0
Takitu-Katui clay	87b	1	1	10.8	<1.0			10.4
Kohumaru clay	88c	2	2	9.1	<1.0	8.7–9.7	<1.0–<1.0	9.0
Mangonui clay loam	89	1	1	7.1	2.1			13.3
Whatoro clay loam	89b	1	1	11.3	<1.0			3.5
Tutamoe clay loam	89d	3	3	12.0	<1.0	11.2–13.6	<1.0–1.1	36.7
Rangiuru clay	90	3	3	9.4	<1.0	5.3–12.0	<1.0–<1.0	14.5
Aranga clay	90a	1	1	10.2	<1.0			10.2
Awarua clay	90b	2	2	10.6	<1.0	10.2–10.9	<1.0–<1.0	10.9
Pakotai clay	90c	1	1	9.1	<1.0			19.0
Ohaewai set (Maunu silt loam)	95	1	1	10.2	<1.0			44.5
Whatatiri clay loam	95b	1	1	12.7	<1.0			13.2
Whakapai clay loam	95f	1	1	11.7	<1.0			2.2
Waiotu set (Apotu friable clay)	96	1	1	7.4	<1.0			49.6
Kerikeri friable clay	96a	1	1	11.2	<1.0			7.5

(Table 3 continued)

Soils†	Soil No.†	No. of Samples	No. 5 p.p.m. & above	Average Cu	Average Mo	Range Cu	Range Mo	Area 000 Acres
Kerikeri set (Tikipunga friable clay)	96a	1	1	10.7	<1.0			
Okaihau set	97a	20	20	8.5	<1.0	5.1–10.4	<1.0–1.8	45.4
Okaihau set (Taraire gravelly friable clay)	97a	1	1	10.1	<1.0			
Hihi set (Hihi gravelly friable clay)	97b	2	2	8.0	<1.0	6.5–9.5	<1.0–<1.0	5.1
Arlington loam	99	1	1	7.2	1.3			2.0
Kaitaia clay loam	101b	3	3	10.0	<1.0	8.3–11.2	<1.0–<1.0	13.6
Kaitaia peaty silt loam	101c	1	1	10.0	<1.0			3.9
Otakairangi loamy peat	110a	1	1	8.7	<1.0			132.1
Bluff loam	113	4	4	6.4	1.2	5.4–8.1	<1.0–1.3	25.7
Whangamomona silt loam	116	2	2	8.8	<1.0	8.8–8.8	<1.0–<1.0	447.0
Whangamomona complex	116a	1	1	7.6	<1.0			182.3
Mangamahu silt loam	116b	4	4	6.1	<1.0	5.3–7.4	<1.0–2.4	87.1
Moumahaki sandy loam	117	1	1	8.3	<1.0			838.7
Makara stony loam	122	3	3	8.7	<1.0	7.0–10.1	<1.0–1.0	275.1
Te Ranga clay loam	122b	3	3	7.3	<1.0	6.8–7.6	<1.0–1.7	317.4
Kaweka sandy silt	125	1	1	7.3	<1.0			402.7
Otanewainuku sandy silt	126	1	1	6.7	2.9			335.4
							TOTAL	6942.0
SOUTH ISLAND*								
Ahaura stony sandy loam		1	1	8.2	<1.0			
Amuri clay loam		3	3	5.9	1.3	5.8–6.1	<1.0–1.7	
Aparima silt loam		2	2	6.4	<1.0	5.3–7.4	<1.0–<1.0	
Ashley silt loam		1	1	8.6	1.0			
Barrhill silt loam		1	1	6.8	<1.0			
Chertsey silt loam		2	2	9.3	1.3	8.7–10.0	<1.0–2.1	
Claremont silt loam		5	5	9.0	<1.0	6.8–11.2	<1.0–<1.0	
Clydevale fine sandy loam		2	2	9.0	<1.0	8.3–9.6	<1.0–<1.0	
(Dipton)* silt loam		2	2	6.5	<1.0	6.2–6.8	<1.0–<1.0	
Drummond silt loam		3	3	7.5	<1.0	7.3–7.8	<1.0–1.0	
Eyre soils (including shallow silt loam, stony silt loam, and stony loam)		9	7	6.5	<1.0	3.8–8.1	<1.0–<1.0	
Glendhu silt loam		4	4	7.5	<1.0	5.9–8.6	<1.0–1.2	
Glenroy silt loam, easy rolling phase		1	1	5.5	1.0			
Heslington silt loam		3	3	9.2	<1.0	8.3–10.5	<1.0–1.6	
Hororata stony silt loam and shallow silt loam		2	1	6.2	<1.0	4.6–7.7	<1.0–<1.0	
Hokitika fine sandy loam		2	2	9.2	1.4	8.5–9.9	1.0–1.7	
Ikamatua sandy loam		1	1	6.7	1.1			
Invercargill loam, and Invercargill peaty loam and peaty silt loam		3	3	7.3	<1.0	6.5–7.8	<1.0–1.7	
Jordan silt loam		2	2	6.6	<1.0	5.6–7.5	<1.0–<1.0	
Kairaki sand		1	1	5.2	<1.0			
Kaiwera silt loam (mottled)		2	2	8.1	<1.0	6.0–10.2	<1.0–<1.0	
Kakahu silt loam, easy rolling phase		1	1	7.4	1.0			
Kauana clay loam		2	2	6.7	<1.0	5.6–7.7	<1.0–1.0	
Kauru silt loam (.....)* (peat stained silt loam on sand, related to Koau silt loam)		3	3	7.6	<1.0	5.9–9.0	<1.0–<1.0	
		1	1	11.2	<1.0			

(Table 3 continued)

Soils†	Soil No.†	No. of Samples	No. 5 p.p.m. & above	Average		Range		Area 000 Acres
				Cu	Mo	Cu	Mo	
Kowai loam		1	1	9.1	<1.0			
Kuri silt loam		1	1	10.8	1.0			
Lismore soils (including shallow silt loam, stony silt loam, shallow stony silt loam)		8	3	5.2	<1.0	4.2-6.2	<1.0–1.1	
Lottery silt loam		1	1	5.3	<1.0			
Lyndhurst silt loam		1	1	8.5	<1.0			
Mahinapua sand		1	1	9.5	<1.0			
Mairaki silt loam		1	1	6.9	<1.0			
Makarewa silt loam (loam and silt loam)		2	2	8.4	1.0	7.6–9.1	<1.0–1.5	
Malakoff silt loam		2	2	6.5	1.1	5.8–7.2	<1.0–1.6	
Mangapiri clay loam		1	1	7.7	<1.0			
Mapua sandy loam		3	3	9.8	<1.0	9.4–10.0	<1.0–<1.0	
Mayfield silt loam and Mayfield shallow silt loam		3	3	7.5	<1.0	6.4–9.5	<1.0–<1.0	
Mokotua silt loam		1	1	8.7	<1.0			
Motunau fine sandy loam		1	1	6.5	<1.0			
Motupiko sandy loam		1	1	8.5	<1.0			
(Moutere)* gravel		1	1	7.9	<1.0			
Oamaru clay loam		1	1	7.2	<1.0			
(Ohai)* soils (clay loam and sandy clay loam)		3	2	6.2	<1.0	4.7–7.7	<1.0–<1.0	
Okarito fine sandy loam		1	1	9.0	<1.0			
Okuku silt loam		1	1	6.3	<1.0			
Omaka gravelly loam		2	1	6.7	<1.0	4.0–9.3	<1.0–<1.0	
Onepunga sandy loam		3	1	5.5	1.4	4.3–6.2	1.0–1.8	
Opuha silt loam		7	7	7.2	<1.0	6.0–8.3	<1.0–<1.0	
Orawia silt loam		2	2	6.2	<1.0	5.7–6.7	<1.0–<1.0	
Otatara loamy sand		2	2	5.7	1.5	5.7–5.7	1.4–1.6	
Otokia silt loam (.....)* fine sandy loam (Taieri Plains)		3	3	9.6	<1.0	9.2–10.1	<1.0–<1.0	
(.....)* silt loam (Taieri Plains)		2	2	10.9	2.0	10.2–11.5	1.2 2.7	
Owaka silt loam		2	2	11.5	<1.0	11.2–11.7	<1.0–1.1	
Oxford silt loam		2	2	6.6	<1.0	5.8–7.3	<1.0 1.0	
Paparua stony sandy loam		1	1	11.8	1.0			
Pikikiruna silt loam		1	1	5.9	<1.0			
Pomahaka loamy sand		4	4	9.3	1.5	8.7–10.2	<1.0–2.7	
Pukemutu silt loam		2	2	10.4	1.9	9.3–11.5	1.2–2.5	
Romahapa silt loam		3	3	5.5	<1.0	5.4–5.6	<1.0 1.1	
Rosedale silt loam		1	1	9.5	<1.0			
Ruapuna very stony silt and Ruapuna stony silt loam		3	3	7.3	<1.0	5.1–10.8	<1.0–<1.0	
Runanga clay loam		5	5	8.5	<1.0	6.7–11.4	<1.0–1.3	
Staveley stony silt loam (bouldery)		1	1	6.3	2.6			
Stirling peat		1	1	5.9	<1.0			
Takahe loam		3	3	8.8	<1.0	6.4–10.7	<1.0–1.0	
Tasman silt loam		1	1	6.6	<1.0			
Te Houka silt loam		1	1	6.8	<1.0			
Te Mara silt loam		2	2	8.0	<1.0	7.7–8.2	<1.0 <1.0	
Templeton silt loam		1	1	5.1	2.4			
Temuka silt loam		4	4	7.8	<1.0	6.3–9.9	<1.0–<1.0	
Timaru silt loam		4	2	8.0	<1.0	4.8–9.5	<1.0–<1.0	
Tisbury complex: loam		3	3	7.6	<1.0	5.8–9.2	<1.0–<1.0	
		3	3	8.0	<1.0	7.2–8.8	<1.0–1.2	

(Table 3 continued)

Soils†	Soil No.†	No. of Samples	No. 5 p.p.m. & above	Average		Range		Area 000 Acres
				Cu	Mo	Cu	Mo	
Waiareka complex: clay loam		7	7	7.4	<1.0	5.8–9.1	<1.0–1.5	
Waikiwi silt loam		2	2	7.3	<1.0	7.0–7.5	<1.0–1.0	
Waikoikoi silt loam		2	2	6.8	<1.0	6.5–7.0	<1.0–<1.0	
(Waimahaka)* loam		2	2	6.8	<1.0	6.0–7.5	<1.0–1.0	
Waimakariri silt loam and Waimakariri shallow sandy loam		6	6	8.6	<1.0	6.2–9.6	<1.0–<1.0	
Waimumu silt loam		2	2	6.9	<1.0	6.4–7.3	<1.0–<1.0	
Waimea clay loam		2	1	7.2	<1.0	4.8–9.5	<1.0–1.1	
Waipara silt loam		1	1	5.6	<1.0			
Wakanui silt loam		1	1	7.9	<1.0			
Wakari brown silt loam		2	2	11.6	<1.0	11.4–11.8	<1.0–1.2	
Warepa silt loam		8	2	8.1	<1.0	4.4–15.4	<1.0–1.4	
Waterton shallow clay loam and Waterton shallow silt loam		2	2	6.3	<1.0	5.7–7.4	<1.0–<1.0	
Wehenga silt loam		2	2	7.9	<1.0	7.3–8.5	<1.0–<1.0	
Willowbridge silt loam		3	3	10.9	<1.0	9.7–12.0	<1.0–<1.0	

† (See footnotes to Table 1)

*

deficiency may occur in animals. Pastures were included only if the mean value for all samples from a soil was below 5 p.p.m. copper and 3 p.p.m. molybdenum. In two cases in South Island pastures, a higher molybdenum figure resulted in inclusion of the soil area in Table 2.

Table 2

Lists pastures which contain 3 p.p.m. or more of molybdenum irrespective of copper content. All pastures from any soil were included if the molybdenum content was 3 p.p.m. or higher in one or more samples. The table shows pastures which should not be topdressed with molybdate because of the risk to stock health from further increases in molybdenum content and includes some pastures in which molybdenum is high enough to cause disease in grazing stock.

Table 3

Lists pastures which contain more than 5 p.p.m. copper and less than 3 p.p.m. molybdenum. On present knowledge these would be regarded as unlikely to cause copper deficiency or molybdenum poisoning in grazing stock.

DISCUSSION

As this investigation was carried out to obtain an estimate of the copper and molybdenum ingested by grazing animals, there can be no question that the analysis of pasture provides the most reliable information. It is, however, desirable to consider whether pasture collected in the spring gives the best estimate and whether the results from a small number of samples taken over a limited area of one soil type can be applied to the whole area of that soil.

Pastures that have made new growth in the spring can be collected at a known stage of growth. This is important since old pastures and stalky growth have been found to have lower copper and molybdenum contents. Spring pastures are more lush and the sward is denser so that the sample is less likely to be contaminated with soil, a contingency which must be avoided to obtain accurate results. Finally it has been found that there is a seasonal variation in molybdenum content of pasture and the value reaches its maximum in spring[1]. For these reasons it was decided that spring samples would give the most accurate and dependable results.

In selecting the soil as the basis for sampling, regard was had to the bases of soil classification. In New Zealand, soils are classified according to the processes by which they are formed. These processes depend on factors such as parent material, topography, the climate, and plant cover, and these factors are believed to have an important influence on the occurrence and availabilty of trace minerals. There is, indeed, already considerable evidence that soil classification can give a very direct lead to the amount of some trace elements that get into plants. Cobalt deficiency in its severe form has been very closely associated with the type of soil[5, 6], and copper deficiency in the North Auckland district has similarly been found to fit into a pattern with soil classification[7, 8].

In respect to molybdenum in pasture, there was already one known parallel between soil and high values for this element in the pasture. Most peat areas at separate points throughout New Zealand were known to produce peat scours in cattle and the disease on each area was shown to be associated with high dietary molybdenum[9]. There was thus the parallel in New Zealand between organic soils and high molybdenum in the pasture. Preliminary studies leading up to the work reported in this paper added further examples. In the South Island, pastures on Weka sandy loam were found high in molybdenum and this characteristic was common to 14 samples at separated points in the same soil. In the North Island the occurrence of disease of cattle on some pumice areas led to the examination of the pasture for molybdenum content. A high value was found to be associated with soils from a particular ash shower and further tests on pasture from other farms have confirmed that where this soil type exists the molybdenum of the pasture is high. At least two other examples of a similar nature occurred. The evidence so accumulated has suggested that considerable reliance can be placed on soil type as a basis for sampling and for extension in the present work. In doing this, the purpose of the investigation was firmly kept in view—it was to act as a guide to those areas where molybdenum excess or copper deficiency might occur so that these factors could be given due consideration in agricultural advisory work.

Some consideration must be given to the criteria adopted to indicate deficient copper or high molybdenum content of pastures.

Most normal pastures in New Zealand contain around 10 p.p.m. of copper. Copper deficiency disease in stock, not complicated by excess molybdenum, has occurred on areas where the pasture contains $3\frac{1}{2}$ p.p.m. or less copper. Copper deficiency in stock induced by excess dietary molybdenum has occurred on pastures containing more than 5 p.p.m. of copper. Having regard to these facts, pastures with less than 5 p.p.m. copper were classified as deficient because they contained much less than

the normal amount of copper and because interfering factors like excess molybdenum could readily induce disease symptoms in stock.

Concerning molybdenum, pastures containing 1 p.p.m. or even less grow well and appear normal and healthy and do not improve from molybdenum added as a topdressing. It can therefore be presumed that more than 1 p.p.m. molybdenum is not necessary for the needs of the plant. From the other angle, the lowest content of molybdenum in the pasture that has been associated with disease in stock is 5 p.p.m. and this in pasture somewhat below normal in copper content. Having these facts available the level of pasture molybdenum at which topdressing with molybdates should be avoided was fixed at 3 p.p.m. Present information does not suggest that 3 p.p.m. molybdenum is likely to cause disease in grazing animals unless copper is very low. Those cases included where the average of all pasture samples from one soil is above 5 p.p.m. molybdenum, however, present a serious risk to grazing stock.

With the considerations discussed above the tables can be reviewed.

The copper deficient areas—Table 1—are relatively small and both Islands would appear to have about the same area affected. It is on these areas that uncomplicated copper deficiency in animals could be expected to occur.

Of more importance in respect to area are the high molybdenum containing pastures shown in Table 2. Such areas are specially extensive in the North Island where there are 52 soils listed covering a total area of about 4 million acres. In the South Island there are 13 soils included but data are not available to estimate the area of these.

Some estimate of the dependability of the methods used to indicate areas of pasture high in molybdenum may be obtained by closer examination of the results in Table 2. Of the 65 soils listed as producing pasture of high molybdenum content there were 56 for which more than one sample was collected, and only for these 56, therefore, can variation between samples be assessed. In 38, or about two-thirds, of these soils molybdenum was present in appreciable amount in every pasture sample analysed. For each of the remaining soils at least one sample was low in molybdenum content. In some of these cases variation was considerable as in the 25 samples from the Manawatu soil set in which the range of molybdenum content was from less than one to 5.8 p.p.m., and in the 14 samples from Hangaroa sandy loam in which the range was from less than one to 10.7 p.p.m. The origin of these apparent anomalies might well be the scale on which the work was undertaken and the soil unit available for reference. There are two soil units used in surveys, the type and the set. The type is employed for detailed surveys and the range within a type is small. The set, on the other hand, is employed for reconnaissance work and is a broader unit defined in *N.Z Soil Bureau Bulletin 5*[4] as a "convenient grouping of soils of like profiles or like assemblages of profiles". It is in the main to soil sets that reference is made in Table 2 and it is not unexpected that variation should occur in pasture samples from some of the soil sets.

Table 2 therefore includes some soils for which the molybdenum content of pastures is uniformly high over the whole area of the soil, and some soil sets of which only some of the area included in the set produces high molybdenum pastures. Molybdenum poisoning is known

to occur in grazing stock on some of these soils and in these cases the average molybdenum content of all pastures was above 4½ p.p.m. The soils which grow pasture with this level of molybdenum are:

* Peat soils
Tukituki set
* Opiki complex
* Konoti clay loam, hill soils
* Tuai coarse sands
* Tihoi-Opa complex
* Tihoi sand
Maramaru coarse sands
Taumarunui sandy silt, hill soils
Matawai sandy loam
* Ahuriri soils
Waihua stony sandy loam
* Moutakarara sandy loam, weakly saline phase
Omihi silt loam
* Weka sandy loam
* Rotomahana sandy loam

Those soils on which disease has been observed are marked with an asterisk. Disease might be expected to occur on the remaining soils listed above and on the high molybdenum parts of the following soil sets:

Manawatu set; Kairanga set; Ngaroma set; Gisborne sandy loam hill soils; Wairama clay and clay loam; Tutira sandy loam; Waipu clay; Otanga peaty loam; Taihape silt loam; Turakina silt loam; Mahoenui silt loam; Hangaroa loam and Harihari fine sandy loam.

It is clearly important for work on animal health that the high molybdenum areas of these soil sets be defined. This will probably come about through separation of soil types within the sets. Examples of how consideration of the molybdenum content of pasture might help in this matter can be quoted from Table 2. The "brown phase" and the "blue phase" of Harihari fine sandy loam produce pastures of distinctly different molybdenum content and the existence of Tuai series of soils in the Taupo set and of the unamed Ngaroma soil in the Ngaroma set were indicated from the high content of molybdenum in the pasture.

The final group of soils in Table 3 are those which have been found to produce pastures normal in copper and molybdenum contents. On these pastures, present evidence would suggest trouble in stock would not be expected from abnormalities in dietary copper or molybdenum.

The data summarized in the tables should not be regarded as more than a general guide in advisory work to be used in conjunction with observations made on individual farms. Nevertheless certain generalisations can be made. Careful search on the high molybdenum pastures from the soils and parts of the soil sets mentioned in the preceding paragraphs might reveal further cases of molybdenum poisoning in grazing stock, especially in cattle which are more susceptible than sheep. The use of molybdates on soils in Table 2 is unnecessary and might indeed do harm to grazing stock by raising the molybdenum content of the pasture to toxic levels. The use of molybdates on soils in Table 1 might similarly be harmful through raising the molybdenum content of pastures which are already low in copper. If molybdate topdressing is necessary to improve pasture production on these soils then copper sulphate topdressing applied at the same time might be desirable to raise the copper content of the herbage and so protect the grazing stock from molybdenum toxicity.

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SELECTION FOR DISEASE RESISTANCE IN LINSEED

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Summary

Results of linseed disease surveys over the period 1948–49 to 1952–53 are presented.

The reaction of a wide range of linseed varieties to flax rust, pasmo, and browning are reported. Bison and Very Pale Blue Crimped were resistant in field trials to pasmo. Calar, Uruguay F.79, and Moose x N.D. F.118 were highly resistant to browning.

Results of a programme for the selection of suitable rust-resistant varieties both by single-plant selection in the local commercial varieties and by selection of suitable varieties introduced from other countries are described. Koto Selns. 5 and 25 are considered suitable replacements for the early variety Koto. Rocket, Redwood, and Daenfeldt are promising as replacements for the mid-season variety Golden Viking.

The genetical basis of rust resistance in Koto is briefly discussed.

Introduction

The acreage of linseed in New Zealand has fluctuated considerably over a long period (N.Z. Official Yearbook, 1955). Though changing world market prices can be regarded as the main factor responsible, the incidence of linseed diseases, flax rust (*Melampsora lini* (Ehrenb.) Lev.), pasmo (*Sphaerella linorum* Wollenw.), and to a limited extent browning (*Polyspora lini* Laff.), has added to the instability of the crop, especially when the acreage was increasing. In the 1947–48 season a widespread rust epidemic caused considerable losses in yield, resulting in a decline in acreage during the next two seasons. Again, when the acreage was at its maximum in the 1952–53 season, pasmo occurred at an epidemic level in mid and south Canterbury in crops of the variety Golden Viking.

Though sound cultural practices can reduce the incidence of the above three diseases appreciably, better insurance was needed against a recurrence of widespread disease attack. A breeding programme was initiated in 1948 aiming to produce linseed varieties immune from rust. In 1953, breeding for resistance to pasmo was included in this programme. Owing to the decline of the linseed industry, breeding work has been terminated. However, testing of overseas varieties, and selection of resistant lines within present commercial varieties, have given results and are reported here, together with the results of disease surveys.

Disease Survey

Surveys to determine the incidence and severity of flax rust, pasmo, and browning in Canterbury, Otago, and Southland, were made from 1948 to 1951. The 1951–52 and 1952–53 surveys were restricted to Canterbury. Crops were visited in mid February of each year. In each crop the incidence of disease was recorded as follows:

* Now at Division of Plant Industry, C.S.I.R.O., Canberra, Australia.

Trace: infected plants difficult to find but definitely present.

Slight: Pasmo and browning; infected plants occurring in small scattered patches (1–3 ft. dia.); about 1% of plants infected.
Rust: few uredosori—confined to leaves.

Moderate: Pasmo and browning; infected plants occurring in larger patches (3–6 yds. dia.); about 10% of plants infected.
Rust: uredosori abundant—confined mainly to leaves.

Severe: Pasmo and browning; large areas infected; 25–100% of plants infected.
Rust: uredosori and teleutosori present on leaves, stems, petioles, and bolls.

Results of the five surveys are listed in Table 1.

TABLE 1. INCIDENCE OF DISEASE IN LINSEED CROPS, 1948–53

Season	Disease	Percentage of Crops Infected					No. of Crops
		Severe	Moderate	Slight	Trace	Total	
1948/49	Rust	15.7	9.4	5.2	26.3	56.6	95
	Pasmo	3.1	9.4	2.1	7.3	21.9	
	Browning	5.2	2.1	5.2	4.2	16.7	
1949/50	Rust	7.4	7.4	15.9	46.8	77.5	94
	Pasmo	8.5	10.6	3.1	17.0	39.2	
	Browning	1.1	4.2	4.2	7.4	16.8	
1950/51	Rust	2.2	10.2	37.7	39.4	89.5	175
	Pasmo	4.0	8.0	9.1	5.7	26.8	
	Browning	0.0	8.5	12.5	1.7	21.7	
1951/52*	Rust	0.0	0.0	28.5	57.1	85.6	56
	Pasmo	5.3	8.9	10.7	17.5	42.4	
	Browning	0.0	3.5	1.7	1.7	6.9	
1952/53*	Rust	1.2	2.4	6.1	22.2	32.9	81
	Pasmo	37.0	33.3	17.3	4.9	92.5	
	Browning	0.0	11.1	17.3	2.4	30.8	

* Canterbury crops only.

The linseed varieties grown commercially during the years under study were mainly Golden Viking and Koto (Canterbury), and Bison (Otago and Southland). Incidence and severity of disease varied from season to season and to a large extent with variety and agricultural practices viz. crop rotation and sowing date. Severe rust infection rarely occurred in crops of any of the above varieties sown at the recommended time (October), but late-sown crops (November and December sowings) suffered severe rust infection in most seasons. Pasmo infection was recorded only on Golden Viking until the 1951–52 season. Severe pasmo infection was confined to this variety. Browning occurred as a minor disease in most seasons in Bison and Koto crops. The serious stem-break symptom was recorded only in the 1948–49 season. All three diseases occurred more severely in areas where linseed crops followed linseed crops in close rotations.

It was evident in the early stages of these surveys that the introduction of disease-resistant varieties would be the most practical control method.

DISEASE REACTION OF INTRODUCED VARIETIES

Rust

Cruickshank (1950, 1951) and Cruickshank and Wright (1953) tested for rust reaction a wide range of linseed varieties introduced into New Zealand for breeding purposes. In the above studies, varietal reaction was classified on the basis of a statistical analysis of uredosorus counts per variety. Although a semi-quantitative inoculation technique was used (Cruickshank, 1950) variation in rust reaction occurred within varieties. The presence of a high percentage of non-infected plants indicated that selection for resistance within varieties would be possible (Table 2).

TABLE 2. RUST RESISTANCE IN INTRODUCED LINSEED VARIETIES

Variety	C.I. No.	Percentage of Plants Resistant to Flax Rust
I.F. 22450/30	—	100.0
Morye	112	97.8
Argentine selection	462	97.2
Rio	280	95.0
Russian x Argentine	896	94.3
Redwood	1130	91.6
I.F. 812, F.82	—	90.5
Tammes Pale Blue	333-1	88.2
B.5128	—	86.6
B.5126	—	83.9
Moose x North Dakota	127	78.1
Rocket	1133	74.9
Uruguay F.79	—	74.3
Daenfeldt	—	66.7
Uruguay F.78	—	61.4
Rio N.Z. Selection	—	56.7
Plate	—	54.4
Uruguay F.77	—	48.9
Malabrigo F.89	696	42.2

(Three tests of 60 plants each. Inoculum—N.Z. races 1–12 except 5. Cruickshank and Wright, 1953)

Pasmo and Browning

Varietal reaction towards browning in linseed has earlier been reported in New Zealand by Baylis (1941). No local studies of varietal reaction towards pasmo have been published.

Field observations in 1951–52 of pasmo incidence in the linseed collection suggested that the varieties Very Pale Blue Crimped and New Zealand Commercial were field resistant. A few other varieties including Bison and Koto were much less severely attacked than the highly susceptible variety Golden Viking. In the 1952–53 season two trials, each of one hundred varieties (5 replications of 25 seeds in beds of 20 varieties randomized in replicated blocks) were grown to study the field reaction of a wide range of linseed varieties towards pasmo and browning. One trial was artificially inoculated with *Sphaerella linorum,* the other with *Polyspora lini,* by spraying at early flowering with a concentrated spore suspension of the respective pathogens on three successive evenings. Varieties were scored with respect to disease reaction at ripening.

Results of the two trials are summarized in Table 3. A list of the balance of varieties which were susceptible to both diseases is presented in Appendix I.

YIELD TRIALS OF RESISTANT VARIETIES

The rust-resistant varieties listed in Table 2 were grown in yield trials at Crop Research Division, Lincoln.

TABLE 3. REACTION OF LINSEED VARIETIES TO PASMO AND BROWNING IN NEW ZEALAND

Variety	Disease Reaction	
	Pasmo	Browning
Bison (C.I. 389)	Resistant	Susceptible
Very Pale Blue Crimped	,,	,,
Bison x C.I. 479	Tolerant	,,
Pernau No. 1	,,	,,
Russian x Argentine F.62	,,	,,
Saginau No. II	,,	,,
N.Z. Commercial	,,	,,
Calar	Susceptible	Highly resistant
Uruguay F.79	,,	,, ,,
Moose x N.D. F.118	,,	,, ,,
3900D	,,	Resistant
3901D	,,	,,
Diadem	,,	,,
Kenya	,,	,,
Korricke III	,,	,,
I.F. 808	,,	,,
J.W.S.	,,	,,
Moose x N.D. F.119	,,	,,
Pergamino	,,	,,
Rio N.Z. Selection	,,	,,

TABLE 4. RESULTS OF VARIETY TRIALS, 1952–53

Trial 1

Variety	Yield (cwt./ac.)	Seed Size (mg./100)	Ripening	Average Score for Pasmo Infection 1–10 (10 is severe)
Golden Viking	16.8	709	mid-season	7.2
Rocket	17.3	743	,,	2.0
I.F. 812	17.6	695	,,	5.8
B.5128	19.2	659	late	2.2
Redwood	20.3	676	mid-season	1.7
Sig. diff. at 5%	5.3			

Trial plots 16 ft x 3 ft. 6 in., randomized, 6 replications, sown 16/10/52.

Trial 2

Variety	Yield (cwt./ac.)	Seed size (mg./100)	Ripening	Average Score for Pasmo Infection 1–10 (10 is severe)
Russian x Argentine	8.5	606	mid-season	3.4
Golden Viking	10.0	650	,,	9.4
I.F. 22450/30	10.3	724	,,	7.0
Moose x North Dakota F.127	10.7	729	very late	2.2
Plate	11.3	699	early	6.0
Morye	12.6	718	mid-season	3.6
Malabrigo	12.9	757	,,	4.6
Daenfeldt	13.0	716	late	4.0
Sig. diff. at 5%	3.2			

Trial plots 6 ft. x 3 ft. 6 in., randomized, replicated 8 times, sown 14/10/52.

B5126, Rio, Rio (Seln.), Tammes Pale Blue, Uruguay, F77, F78, F79, and Argentine Seln. C.I. 462 were discarded after the first season's (1951–52) observations, mainly on account of late ripening and/or low yield. Table 4 summarizes the performance of the remaining varieties during the 1952–53 season.

The spring and early summer of 1952 were unusually wet. Pasmo infection became very serious throughout the major linseed-growing areas, including trials at Lincoln. The varieties Golden Viking, I.F.-812. Plate, I.F.-22450/30 were highly susceptible to this disease.

TABLE 5. RESULTS OF VARIETY TRIAL, 1953/54

Variety	Yield (cwt./ac.)	Seed Size (mg./100)	Ripening
Golden Viking	14.6	676	mid-season
Morye	15.2	700	mid-season to late
Malabrigo	15.6	703	mid-season to late
Rocket	15.8	630	mid-season
Daenfeldt	16.3	723	late
Redwood	16.5	587	mid-season
Sig. diff. at 5%	1.66		

Trial plots 16 ft. x 3 ft. 6 in. randomized, 6 replications, sown 2/11/53

The varieties Redwood, Rocket, Daenfeldt, Malabrigo, and Morye were tested in a further trial, the results of which are presented in Table 5.

Redwood, Rocket, and Daenfeldt appeared to be the most attractive varieties, although Daenfeldt ripened late in both seasons, possibly too late for New Zealand conditions. However, successful selection, especially for earlier-ripening plants, seemed possible in the varieties Daenfeldt and Malabrigo, which were rather heterogeneous. Another advantage in Daenfeldt was the consistently heavy weight of the seeds in spite of the dry conditions in 1953–54. Further selections within the varieties Redwood and Rocket have been made in an attempt to obtain a uniform degree of rust resistance.

A further rust race (N.Z. 9, Cruickshank, 1956) was identified in December 1952 which was pathogenic to these selections. Its incidence up to the present time has however been very limited.

Single-plant Selection for Rust Resistance within Commercial Varieties

In 1948, plant populations of the commercial varieties Walsh, Victory, Koto, Moose, Golden Viking, and Bison were tested with a representative sample of uredospores at Plant Diseases Division, Auckland.

Resistant plants were obtained from the varieties Walsh, Victory, Koto, and Moose only. Subsequent field observations and glasshouse tests on their progenies showed that only the selections Koto 5 and Koto 25 were worth including in further trials. Results of these trials are given in Table 6.

Both selections were distinct from the original population. Koto 25 showed a more rapid development, flowered earlier, and matured earlier than Koto. Koto 5 was taller than Koto 25 and Koto, developed

TABLE 6. Results of Variety Trials, 1952–54

Variety	1952/53 (sown 16/10/52)			1953/54 (sown 2/11/53)		
	Yield (cwt./ac.)	Seed size (mg./100)	Ripening Date	Yield (cwt./ac.)	Seed size (mg./100)	Ripening Date
Koto	15.2	635	29/1/53	12.1	543	9/2/54
Koto 5	14.9	558	1/2/53	14.7	490	11/2/54
Koto 25	17.8	589	24/1/53	13.7	530	6/2/54
Marine†	—	—	—	12.4	537	8/2/54
Sig. diff. at 1%	2.2			2.4		
at 5%	1.5			1.6		

Trial plots 16 ft. x 3 ft. 6in. randomized, replicated 6 times.

† Marine is the present main commercial variety, which was included in the 1953/54 trial after showing a high degree of field resistance against pasmo during the 1952/53 season. It is resistant to all rust races recorded in New Zealand except race 12.

more slowly, flowered at the same time, but matured some days later than Koto. The seeds of both selections were smaller than Koto, although seed varied considerably in size from season to season.

Another rust race (N.Z. 8, Cruickshank, 1956) was identified in July 1952 which could infect both selections in the glasshouse. The type of reaction (pustule type '2') indicated that the above two linseed selections would show high field resistance.

VARIABILITY OF KOTO TO INDIVIDUAL RACES OF RUST

A study of the reaction of Koto to (N.Z. races 1, 4, 5, 7, 8, 10, 12) (Cruickshank, 1956) indicated that it could be classified into groups, each with a specific reaction (Table 7).

TABLE 7. KOTO PLANTS GROUPED ACCORDING TO THEIR REACTION TO SEVEN RUST RACES

Group	Reaction to individual Races							Number of Plants in Group	Percentage Total Number of Plants
	1	4	5	7	8	10	12		
I	R	R	R	R	R	R	R	12	16.7
II	R	R	R	R	S	R	R	51	70.8
III	S	S	S	S	S	S	S	2	2.8
IV	R	S	R	R	S	S	S	5	7.0
V	R	R	R	R	S	S	S	1	1.4

R = resistant (0–2 pustule type)
S = susceptible (3–4 pustule type)

Each individual plant of a random sample of 72 plants from the commercial variety was tested by using a technique which made repeated testing of one single plant possible (Kerr, 1952).

With some reservation, four groups of a different genotype for resistance could be distinguished of which one group is resistant to all known New Zealand races of rust. This indicates that further selection for resistance to race 8 would be possible.

DISCUSSION AND CONCLUSIONS

From the results of disease surveys of linseed crops over the seasons 1948–49 to 1952–53, it is evident that diseases are an important factor in the growing of this crop. Incidence of disease depends on varietal susceptibility, date of sowing, and climatic conditions. For instance, the incidence of serious rust infection has declined continuously since autumn sowing of linseed has been abandoned and field-resistant varieties* introduced in 1948–49.

* Prior to 1948 the very susceptible variety Bison was grown in all districts in New Zealand.

Rust and pasmo are still the most important diseases. Browning, although widespread in the growing areas, has rarely occurred in its stembreak phase since the 1948 49 season and has not been responsible for serious loss since that time.

Results of disease testing and breeding work on linseed have shown that relatively quick results can be obtained by selection of resistant material in present commercial varieties and by testing overseas varieties with a high proportion of resistant plants. By the first method, selections have been made (viz. Koto Seln's 5 and 25) which may be suitable as replacements of the early variety Koto. By the second method, Rocket, Redwood, and Daenfeldt have been shown to be promising as replacements for the mid-season variety Golden Viking. In both instances, however, further field trials of these varieties will be necessary if the linseed acreage again increases to that of an important agricultural crop in this country.

Two races (N.Z. 8, 9) have been identified which are capable of attacking the Koto and Redwood selections respectively. However, the selected varieties can be expected to remain field resistant for several years. In addition, there is evidence that further selection for resistance to race 8 is possible in the variety Koto. A study of the heterogeneity of this variety towards rust revealed that at least 4 different genotypes are present. A possible explanation for the heterogeneity of this variety is that two genes for rust resistance were in a heterozygous condition at the time of its selection. Morye, one of the parents of the cross (Reserve x Morye) x Bison from which Koto was selected (Dillman, 1946), carried 3 rust-conditioning genes (Flor, 1954). When the selection was made, one of these three genes might have been sufficient to confer complete resistance to the rust races at that time (1935), masking the heterozygous condition of genes which showed their effect later on with the change in the rust-race population.

Varietal resistance to pasmo and browning has been shown to be present in some of the introduced varieties (see Table 3). Some of these varieties may be suitable as parent material in future breeding projects.

APPENDIX I

List of Varieties Tested and Found Susceptible to both Pasmo and Browning.

Arrow
Argentine (C.I. 462)
Akmolinsk (C.I. 515-1)
Abyssinian (C.I. 701)
Bison x C.I. 36.928
Bison x C.I. 679
Bison x Newland 38-C890
Bison x Newland 38-C1321
Biwing
Beladi
Buda (C.I. 270-1)
Bombay (C.I. 42)
Bolley's Golden F.16 and F.17
Bolley's Golden 977
Bolley's Golden 644
B.5126
B.5128
C.I. 679
C.I. 1085
C.I. 1153
C.I. 1155
Crystal
Dakota
Daenfeldt
F. 81
F. 83
F. 93
F. 145
F. 146
F. 149
Golden Viking
Hindi
I.F. 22450/30
I.F. 812
Kharramabad
Koto
Korricke I.
Korricke II.

Leona
Malabrigo F. 89
Moose 13/28
Moose 16/28
Moose 11/29
Moose x N.D. 125
Maramko
Morye (C.I. 112)
Minami
Moroccan
Marine (C.I. 1135)
North Dakota 52
North Dakota 73
North Dakota 114
Newland (C.I. 188)
Nansho
Novelty
Ottawa 770B (C.I. 355)
Punjab
Punjab Seln.
Plate
Royal
Russian x Argentine x Bison
Redwood
Redwing
Rio
Rocket
Sheyenne
Seln. 5872 F.144
Saginau x Bombay F. 19
Saginau No. 1
Sadd's English
Tammes Pale Blue
Uruguay F. 77
Uruguay F. 78
Valuta
Vaanila
Walsh
Williston Golden (C.I. 281)
Williston Brown (C.I. 803-1)

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MOLYBDENUM CONTENT OF PASTURE AFTER TOPDRESSING WITH MOLYBDATES

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Summary

The effect of molybdate topdressing on the molybdenum content of pasture was found to differ markedly with the soil type to which the molybdate was applied.

Pasture samples from field topdressing trials showed that seven soils in the North Island, representing 20% of the area of the 64 North Island soils examined, gave an abnormally high response to the usually recommended rate of about 2 oz. molybdate per acre, while none of 50 South Island soils examined showed a similar effect. Pastures from all these soils had normal molybdenum contents before topdressing.

Detailed studies are reported of pasture molybdenum after topdressing high-responding and low-responding soils. In each case there was a direct relationship between the amount of molybdenum found in the pasture and the amount applied, but on responsive soils the increase was much higher and more persistent. Perennial ryegrass took up slightly more molybdenum than white clover from molybdate topdressings.

Attention is drawn to the need for considering response before molybdate is employed as a topdressing, so as to avoid inducing molybdenum levels that might be toxic to grazing stock, and a number of the responsive soil types have been identified. Cobalt topdressings at 5 and 10 oz. cobalt sulphate per acre did not affect the molybdenum content of pasture.

Appreciable transfer of molybdenum from topdressed to adjacent untopdressed plots occurred in the excreta of grazing sheep used to control the pasture growth on the plots.

Introduction

In some districts of New Zealand very marked growth responses in pasture and in crops result from small applications of molybdates as fertilizers. Lobb[1] in this connection has shown that the extra pasture so obtained in parts of the Waimate county can improve the stock carrying capacity by as much as 60% which is an impressive increase from a topdressing of the order of 2 oz. per acre.

Molybdate fertilizers have another appeal. Davies, Holmes and Lynch[2] have suggested that the growth response in pasture to very heavy applications of lime might be the result, in Southland at least, of increased availability of molybdenum resulting from the increased pH of the soil. This has suggested the possibility that molybdate topdressings might in part replace lime for pasture improvement, a possibility that holds considerable interest for those engaged in the improvement of hill country that is easily accessible for topdressing from the air but costly or in some cases impossible to topdress from the ground.

For such very good reasons, molybdates are being increasingly used as a topdressing for pastures and other crops.

But while molybdenum in small amounts is essential for plant growth, molybdenum in large amounts in the fodder is definitely harmful

to stock living on such fodder. Molybdate topdressings must be used with care and in such a way that excessive amounts do not accumulate in the herbage.

The experimental work described in this paper emphasizes the need for this care, by showing the high response in pasture molybdenum to repeated topdressings of molybdates. An examination has also been made of response in pasture molybdenum to single topdressings, on a wide selection of soils, so as to show which soils are safe to topdress and which respond abnormally by giving high molybdenum contents in the pasture grown.

Experimental Methods and Results

Analytical Methods. Copper was determined in the dried grass by the method described by Clare, Cunningham, and Perrin[3] and molybdenum by Perrin's method[4]. The results are expressed as parts per million (p.p.m.) of dry grass.

Plot Experiments. Five plot experiments were carried out to determine the effects on molybdenum content of pasture of different rates and of repeated topdressings with molybdate.

Experiment 1

This was at Flock House Farm of Instruction, Bulls, and the soil was Himatangi sand.

Molybdate topdressing was included as part of a larger trial on the effects of topdressing with copper salts and there were two groups of plots, identically treated and separated by about 100 yards in the one paddock. Five $\frac{1}{200}$-acre plots in each group were used for molybdate topdressing, and the topdressing on every plot was at the rate of 3 cwt. superphosphate and 2 oz. ammonium molybdate (= 30.4 g. molybdenum) per acre, and on individual plots at the rate of 0, 5, 10, 15, and 20 lb. copper sulphate per acre. Topdressings were applied on three occasions—28 November 1951, 30 November 1952, and 16 April 1953. Control areas were five plots in each group treated with the same amounts of superphosphate and copper but no molybdenum.

The first pasture samples were cut in November 1951 just before topdressing, and subsequent samples were taken at intervals shown in Fig. 1, up to the last in October 1955. Plots were grazed by sheep after each sampling and shut up for a suitable period before the next sampling to give a clean growth of grass which was usually four to six inches high when sampled.

Results are given in Fig. 1. Each plot was sampled and analysed separately but as there was no difference in molybdenum content of pasture resulting from different levels of copper sulphate applied, the results for all the control plots and for all the topdressed plots were separately averaged.

Fig. 1 depicts these average results from ten control plots and from ten plots topdressed three times with 2 oz. ammonium molybdate per acre.

The untopdressed areas showed consistently a content of less than 1 p.p.m. molybdenum in the dry grass. In contrast, the molybdenum content of pasture from topdressed areas rose to 5.4 p.p.m. after one

Fig. 1.—Molybdenum contents of control and topdressed plots on Himatangi sand. Topdressing 2 oz. ammonium molybdate per acre at times indicated.

topdressing, fell off over the next twelve months, and rose again to 4.8 p.p.m. after the second topdressing, again fell but rose to 10.6 p.p.m. after the third topdressing and remained near that figure for the succeeding seven months. Thereafter the molybdenum fell to about half but stayed around that level and was still 5.4 p.p.m. molybdenum thirty-one months after the third topdressing.

Experiment 2

This was at Wallaceville with an enclosed group of plots each $\frac{1}{200}$ acre in area on a very stony phase of Heretaunga silt loam.

There were thirty-two plots topdressed with molybdate, two control plots, and further control samples were collected from the untreated area between the plots and an enclosing fence. The plot enclosure was part of an area sown down to pasture in 1952 after clearing away a light cover of beech and totara trees. Before 1952 there was no topdressing applied. In March 1952, 2 cwt. superphosphate and one ton lime per acre were applied; in September 1952, 3 cwt. superphosphate was applied when the grass mixture was sown, and a further 3 cwt. superphosphate in the autumn of each year 1953, 1954, and 1955.

Molybdate topdressing was applied in solution at the rates of 1 oz., 2 oz., 4 oz., and 8 oz., ammonium molybdate per acre. For each rate of topdressing there were eight plots, all of which were topdressed on 24 June 1953 and 26 April 1954. Two of these plots had no further topdressing but six received a third topdressing on 23 March 1955.

The first samples were taken on 24 June 1953 just before molybdate topdressing, and subsequent samples were taken on dates shown on Fig. 2 up to 28 September 1955. Samples from each plot and control area were analysed separately.

After each sampling the plots were grazed by sheep brought in from a surrounding area that had been topdressed with molybdate so that the pasture contained about 6 p.p.m. molybdenum. The plot enclosure was shut up for a period before each sampling so that pasture grew to a length of four to six inches.

The average copper and molybdenum results for all areas treated the same way are shown in Fig. 2 which depicts:

1. Copper and molybdenum in control samples.
2. Copper and molybdenum in plots topdressed with 1 oz. ammonium molybdate per acre.
   The full black molybdenum line shows the mean figures for plots topdressed twice and the mean figure for plots topdressed a third time is shown by a broken line as indicated in the legend to the figure.

3. As for 2 but 2 oz. ammonium molybdate per acre.
4. As for 2 but 4 oz. ammonium molybdate per acre.
5. As for 2 but 8 oz. ammonium molybdate per acre.

The results show a close relationship between rate of molybdate topdressing and level of molybdenum in the pasture. A topdressing of 1 oz. ammonium molybdate per acre raised the pasture content to about 3 p.p.m. and subsequent annual topdressings at the same rate maintained

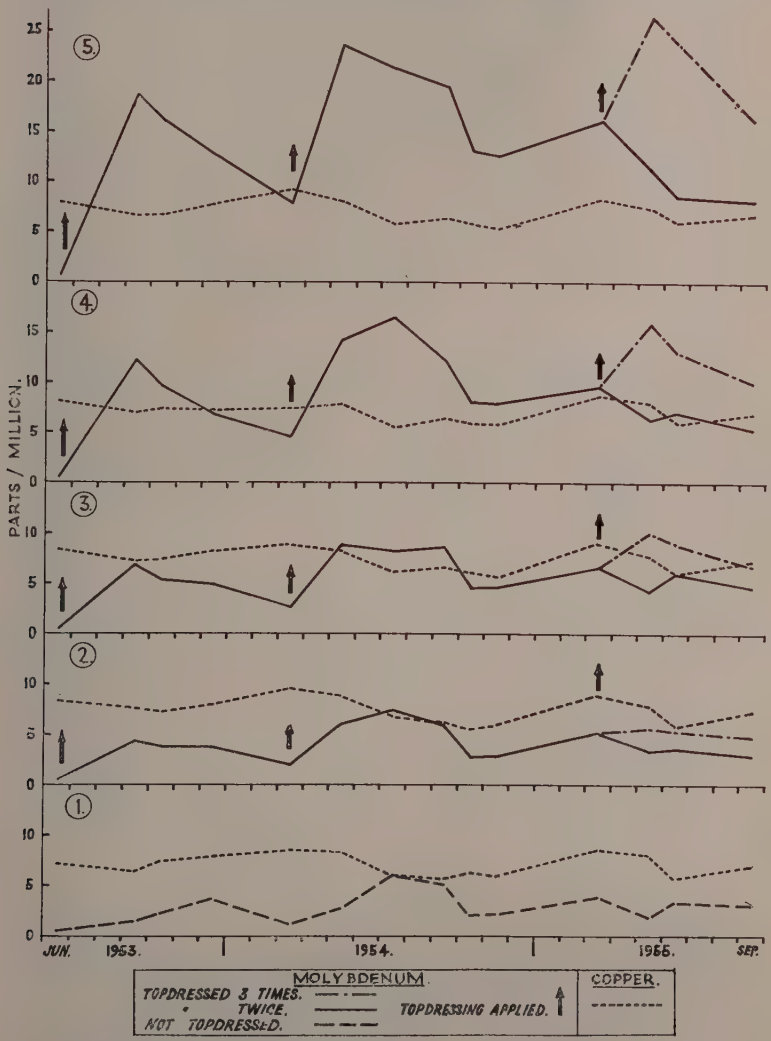

Fig. 2.—Molybdenum and copper contents of control and topdressed plots on Heretaunga silt loam. Topdressing at rates of ammonium molybdate detailed in text and at times indicated in figures.

this level; 2 oz. per acre kept the level about 6 p.p.m.; 4 oz. per acre kept the level about 10 p.p.m., and 8 oz. per acre kept the level around 17 p.p.m. Pasture from the two plots at each rate which were topdressed only twice was falling off in molybdenum content at the time observations were discontinued. Nevertheless, seventeen months after a second annual topdressing of 1 oz. ammonium molybdate per acre the pasture contained 2.8 p.p.m. molybdenum, and corresponding figures for rate of 2, 4, and 8 oz. per acre were 4.6, 5.3, and 8.1 p.p.m. molybdenum respectively. The high level reached by pasture molybdenum relative to copper is illustrated in the graphs. The 2 oz. per acre rate kept pasture molybdenum approximately the same as pasture copper, and for higher rates the pasture molybdenum was substantially above pasture copper.

The control plots also showed considerable increases above the figure of about $\frac{1}{2}$ p.p.m. molybdenum that was present at the beginning of the experiment. The shape of the curve is similar to those for topdressed plots though at a lower level and this suggests application of molybdenum in some form.

The only possible source was from the excreta of grazing sheep, and as will be discussed later this could very well acount for the observed effect.

Experiment 3

This was designed to supplement the information obtained from Experiment 2 but each plot was separately enclosed so that when it was grazed off there should be no transfer of molybdenum from other plots in the excreta of grazing animals.

The plots were laid down near those of Experiment 2 on land with an identical history though the soil differed slightly and was a stony phase of Heretaunga mottled silt loam.

There were twelve plots topdressed with molybdate and three control plots. Molybdate topdressing was applied in solution at the rates of 1 oz., 2 oz., and 4 oz., ammonium molybdate per acre. For each rate of topdressing there were four plots all of which were topdressed on 15 April 1954. One plot for each rate had no further topdressing but three received a second application of molybdate on 22 March 1955.

The first samples were collected on 15 May 1954 and subsequent samples at times shown in Fig. 3 until the last on 10 October 1955. Samples for each plot were analysed separately.

After each sampling, plots were grazed by sheep brought in from an area where the molybdenum in the pasture was less than 1 p.p.m. and the area was not grazed for a suitable period before sampling so that the pasture grew to a length of four to six inches.

The average copper and molybdenum results from all areas treated the same way are shown in Fig. 3 which depicts:

1. Copper and molybdenum in control samples.
2. Copper and molybdenum in plots topdressed with 1 oz. ammonium molybdate per acre.
   The full black molybdenum line shows the mean figure for plots topdressed once and the mean figure for plots topdressed twice is shown by a broken line as indicated in the legend to the figure.
3. As for 2 but 2 oz. ammonium molybdate per acre.
4. As for 2 but 4 oz. ammonium molybdate per acre

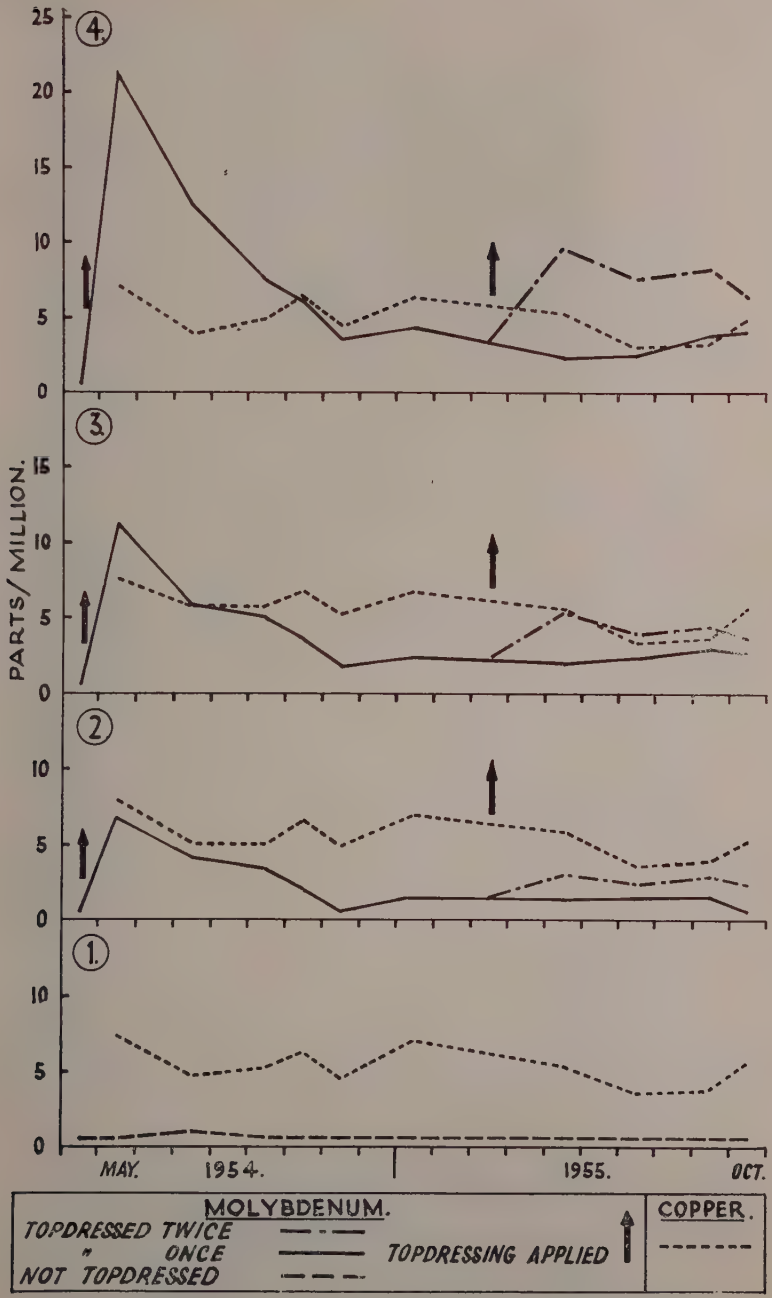

Fig. 3.—Molybdenum and copper contents of control and topdressed plots on Heretaunga mottled silt loam. Topdressing at rates of ammonium molybdate detailed in the text and at times indicated in the figures.

In considering results for experiments such as that described above, abnormally high values for the first pasture samples taken after topdressing should be disregarded because of the likelihood of direct contamination on leaves of pasture plants from the topdressing. With due allowance for this variable effect on first samples, the response to the same rates of molybdate topdressings were slightly lower but otherwise similar to those in the previous experiment. In this experiment any complication due to possible transfer of molybdenum by grazing animals was excluded by the design, and the consistent low figures for control plots confirms that the design was effective.

The results show a direct relationship between molybdenum content of pasture to rate of topdressing by molybdates, an enhanced effect from a second topdressing about one year later and a persistent effect on pasture molybdenum content from one topdressing with even as low a rate as one ounce per acre.

Experiment 4

This was a trial carried out by Mr. N. A. Cullen at Invermay Station and we are indebted to Rukuhia Soil Research Station for some of the analytical figures and to Mr. Cullen for permission to quote the results.

The experimental area was on Warepa silt loam (on loess with phonolite) and had received two tons lime and 6½ cwt. superphosphate per acre in the three years before the trial was started. No lime or superphosphate was used at laying down or subsequently. Plots were 10 x 5 ft. ($\frac{1}{870}$ acre) with 5-ft. buffers between. There was a control plot and plots topdressed at the rate of 1.23, 2.46, 4.92, 9.84, and 19.68 oz. sodium molybdate per acre. At each rate of topdressing one plot was topdressed once, one topdressed twice, and one three times at dates shown in Fig. 4. The molybdate was applied by spraying a solution in water.

The plots were not grazed but were mowed when the pasture was three inches to four inches high and the clippings after sampling were returned to the plot from which they were cut. The first samples were cut on 2 October 1953 and subsequent samples on the dates shown in Fig. 4.

Results are shown in Fig. 4 which depicts:

1. Molybdenum in pasture from control plot.
2. Molybdenum in pasture from plots topdressed at the rate of 1.23 oz. sodium molybdate per acre. The full black line represents the plot topdressed once and results from plots topdressed twice and three times are shown by the symbols indicated in the legend.
3. As for 2 but 2.46 oz. sodium molybdate per acre.
4. As for 2 but 4.92 oz. sodium molybdate per acre.
5. As for 2 but 9.84 oz. sodium molybdate per acre.
6. As for 2 but 19.68 oz. sodium molybdate per acre.

Fig. 4 shows that on Warepa silt loam (on loess with phonolite), as on Heretaunga silt loam, the response in pasture molybdenum increased almost in direct relation to the rate of topdressing applied. There was a notable difference in the magnitude of the response on the Warepa

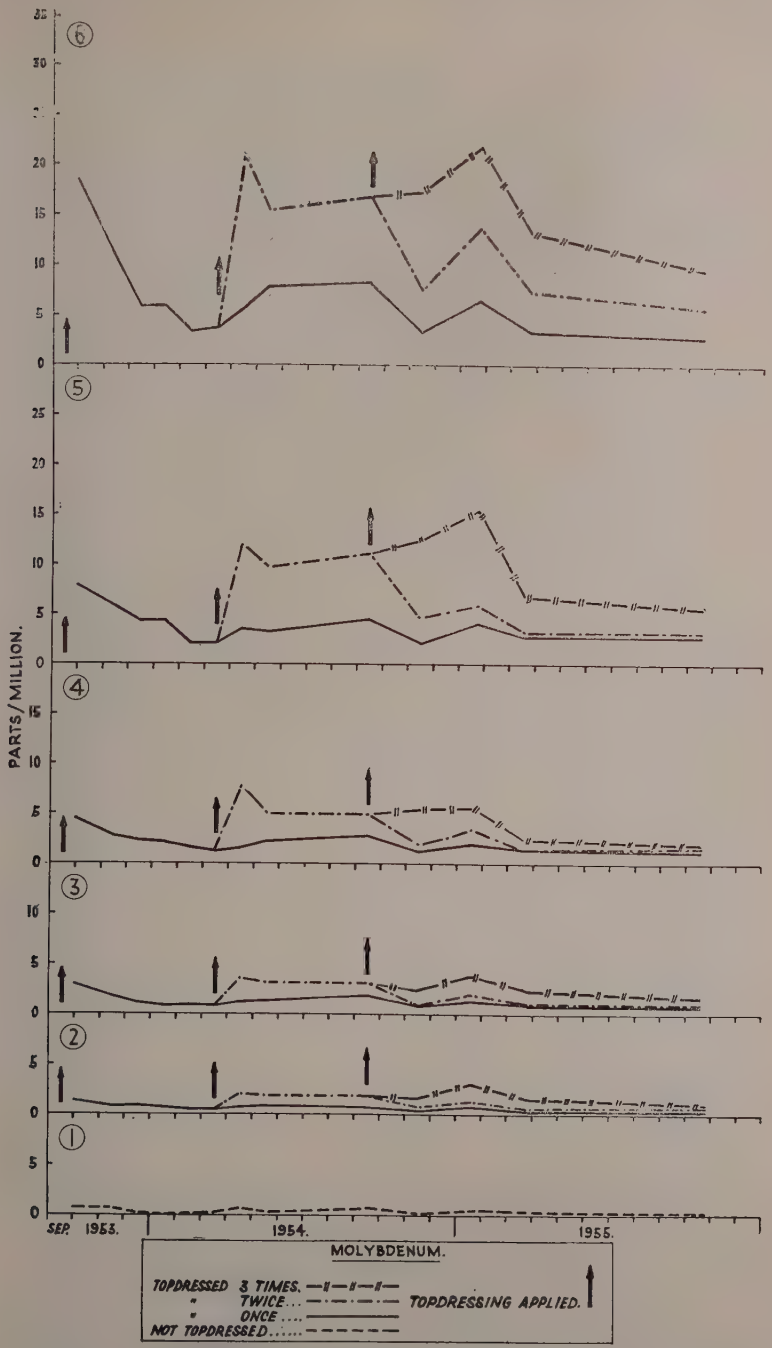

Fig. 4.—Molybdenum contents of control and topdressed plots on Warepa silt loam (on loess with phonolite). Topdressing at rates of sodium molybdate detailed in the text and at times indicated in the figures.

silt loam compared with that recorded in Figs. 1, 2, and 3 for Himatangi sand and Heretaunga silt loam. On the Warepa silt loam three topdressings each of 2.46 oz. sodium molybdate per acre produced a maximum pasture content of 3.9 p.p.m. molybdenum and the figure had dropped to 1.9 p.p.m. eleven months after the final topdressing. In contrast, on Himatangi sand three topdressings of 2 oz. ammonium molybdate per acre applied within a period of seventeen months produced a maximum pasture content of 13.0 p.p.m. molybdenum and the figure was 5.4 p.p.m. thirty-one months after the last topdressing. On Heretaunga mottled silt loam the response to one topdressing of 2 oz. ammonium molybdate per acre was about equal to that on the Warepa silt loam from one topdressing of 9.84 oz. sodium molybdate per acre.

These differences appear to be due to the soil type in which the topdressing was carried out and further examples of this phenomenon are discussed below.

Experiment 5

This was carried out at Grasslands Division, Palmerston North, where the soil is Manawatu silt loam.

The purpose was to determine the uptake of molybdenum by grass and by clovers growing in association, after a single topdressing of molybdate.

Eight plots each 20 x 6 ft. ($\frac{1}{363}$ acre) were made available by Dr. P. D. Sears. Four plots had been sown with perennial ryegrass, H1 ryegrass, and Pedigree No. 1 white clover, and the other four with perennial ryegrass, H1 ryegrass, and Mt. Barker strain of subterranean clover. There were four treatments: nil, superphosphate alone, molybdate alone, and superphosphate plus molybdate, each applied to two plots of which one was sown with white clover and the other with subterranean clover.

Superphosphate was applied at the rate of 4 cwt. per acre in March and in September 1950. There was no response in pasture growth to these topdressings which suggests that there was adequate phosphate in the soil of all the plots. Sodium molybdate was sprayed on in solution on 6 September 1950 at the rate of 4 oz. per acre.

The plots were not grazed but were mowed when the growth reached a suitable length. The first cut after topdressing was discarded because of the possibility of direct contamination of pasture by molybdate at the time of topdressing. The second and third cuts from all plots and the fourth cuts from white clover plots were collected and the grass and clover separated for analysis. Fourth cuts could not be taken from subterranean clover plots as at that time, with dry summer weather, the clover had ceased to grow.

Results are shown in Table 1. The plot numbers in the table show the source of the samples and hence which grass and clover samples were grown together.

These results show that the grasses and subterranean clover and grass and white clover, growing in association, took up subtantially the same amounts of molybdenum from a single topdressing of sodium molybdate. There was considerable variation between plots but in

TABLE 1. MOLYBDENUM CONTENT (P.P.M. IN D.M.) OF GRASS AND CLOVERS (GROWING TOGETHER) AFTER ONE MOLYBDATE TOPDRESSING

Months after top-dressing when sampled	Untreated or + Super.				4 oz. Sodium Molybdate per Acre				Super. + 4 oz. Sodium Molybdate per Acre			
	Grass	Sub. Clover	Grass	White Clover	Grass	Sub. Clover	Grass	White Clover	Grass	Sub. Clover	Grass	White Clover
2nd cut 1⅔	0.5	0.2	0.7	0.3	3.9	2.0	7.3	6.6	2.3	1.6	3.2	4.5
3rd cut 2⅔	0.3	0.4	0.5	0.4	1.0	3.5	4.8	3.4	0.9		1.3	2.5
4th cut 4			0.3	0.2			7.7	4.8			2.5	4.5
Plot No.	1 & 2	1 & 2	3 & 4	3 & 4	5	5	6	6	7	7	8	8

every topdressed plot, molybdenum in herbage rose above that in control and for individual plots the rise was similar in grass and clover.

Further results are given in Table 2 for samples taken from paddocks topdressed with ammonium molybdate and grazed by sheep. As indicated in the table, three paddocks had been topdressed several times in a period of three years, six had been topdressed once only and five were not topdressed. Samples were taken by clipping randomly selected areas on the paddock and separating all the white clover and the ryegrass collected. The main components of the pasture were white clover and ryegrass in approximately equal proportions and the soil was Heretaunga mottled silt loam.

TABLE 2. MOLYBDENUM CONTENT (P.P.M. IN D.M.) OF GRASS AND CLOVERS (GROWING TOGETHER) AFTER MOLYBDATE TOPDRESSING

Total ammonium molybdate applied oz./ac.	No. of Separate Applns.	No. of Topdressed Paddocks	Date (a) 1st Appln. (b) Last Appln.	Date Sampled	Molybdenum Content	
					Perennial Ryegrass	White Clover
14	6	2	(a) 8.7.53 (b) 20.4.56	15.5.56 25.5.56	14.3 13.1	13.0 7.2
12	5	1	(a) 8.7.53 (b) 20.4.56	16.5.56	12.0	8.2
6	1	4	(a) 12.12.55	11.5.56 „ „ 25.5.56	8.5 9.8 7.0 12.1	6.2 7.8 6.4 7.6
6	1	2	(a) 2.2.56	17.5.56	9.3 9.5	6.0 8.2
Nil		5		17.5.56	All less than 1 p.p.m.	All less than 1 p.p.m.

The results in Table 2 show, as did those in the previous table, that molybdate topdressing raised the molybdenum content of both perennial ryegrass and white clover. The increases were similar in magnitude but in most cases ryegrass was higher.

Tables 1 and 2 both refer to rates of topdressing somewhat higher than applied in normal farm practice and a difference in response between species may yet be observed with smaller rates of topdressing.

Indications of similarity of molybdenum content in grass and legumes growing in soil not topdressed but naturally high in molybdenum were to be seen from samples collected on Rotomahana sandy loam and on peat. Perennial ryegrass and broad red clover collected on the same day as separate samples from Rotomahana sandy loam were found to contain 6.7 p.p.m. and 4.3 p.p.m. respectively while from peat at Torehape, on the Hauraki Plains, Yorkshire fog contained 2.8 p.p.m. and lotus major 3.5 p.p.m. molybdenum.

Molybdate Topdressing and Soil Type

A number of instances had been observed of considerable difference in the molybdenum content of pasture after molybdate topdressing, when the topdressing was applied to different soils. One such instance is recorded in detail in Experiments 4 and 3 of this paper which show that there was a much lower and less persistent effect on pasture molybdenum from molybdate applied to Warepa silt loam (on loess with phonolite) at Invermay than from the same rates of topdressing on Heretaunga silt loam at Wallaceville. Because magnitude of response could have an important bearing on the use of molybdate topdressing in farm practice, the effects of topdressing have been measured on a large number of different soils. For this work arrangements were made with Agricultural Instructors to forward pasture samples from trials that had been laid down to test the response in pasture growth on soils in their districts.

Each trial usually contained an untreated plot, a plot topdressed with molybdate at about 2 oz. per acre, and a plot topdressed with molybdate and lime. The salt of molybdenum used was commercial sodium molybdate which contained about 40% molybdenum. Instructors were asked to collect spring growth of pasture from each of the three plots, to dry the samples and to forward dried samples to this Station, with information on date of topdressing and date of sampling. The desire to have spring samples made it impossible to arrange for pasture samples to be taken at a standard interval of time after topdressing.

The samples were analysed for copper and molybdenum and results are given in Tables 3 and 4 for 138 plot trials from 114 soils. All these soils except one grew pasture that contained less than 3 p.p.m. molybdenum before topdressing. The exception is Pongakawa shallow peaty loam which is included to show the effect of liming on the molybdenum content of pasture from a peat soil. The soil type was confirmed by a pedologist in 74 cases and the remaining 40 soils were identified by an Agricultural Instructor.

Table 3 lists those soils from which pasture contained 3 p.p.m. or more of molybdenum in samples taken at least three months after topdressing and Table 4 lists soils from which topdressed pasture samples contained less than 3 p.p.m. molybdenum. For reasons put forward in a

previous paper[5], 3 p.p.m. or more of molybdenum in pasture has been regarded as too high for definite safety of grazing stock. Three months after topdressing was taken as a sufficient lapse of time for contamination from topdressing to disappear and for the result to represent true pasture molybdenum.

North Island and South Island samples are included in the appropriate table but are grouped separately. The first column shows the soil name and for the North Island samples the second column shows the number allotted to that soil in *N.Z. Soil Bureau Bulletin 5*[6]. Subsequent columns

TABLE 3. RESULTS OF FIELD TOPDRESSING TRIALS. SOILS FROM WHICH PASTURE SAMPLES CONTAINING 3 OR MORE P.P.M. MO AFTER TOPDRESSING

NORTH ISLAND†

Soil†	Soil No.	Control Plot		Mo Top-dressing	Sample Months after Top-dressing	Molybdenum Plot		Lime Top-dressing	Molybdenum plus Lime Plot		Area 000 Acres
		Mo p.p.m.	Cu p.p.m.	oz./ac.		Mo p.p.m.	Cu p.p.m.	cwt./ac.	Mo p.p.m.	Cu p.p.m.	
Tarawera gravel	5	2.3	8.1	2½	1	6.2	6.5	15	5.9	6.2	63.5
		2.4	6.9		13	4.3	7.5		5.0	6.3	
Rissington set (Crownthorpe sandy loam, hill soils)	11cH	1.2	7.0	2½	17	2.0	5.5	60	3.5	5.5	16.2
Marton loam	13c	<1.0	7.5	2½	2	5.0	7.3	60	6.0	9.6	118.6
		<1.0	7.5		13	3.6	8.1		4.5	6.4	
Te Kopuru sand	47d	<1.0	4.1	2½	9	3.1	6.1	40	3.5	3.1	93.2
		1.3	3.4		21	2.3	5.8		3.5	2.4	
Ohakune silt loam	65	1.5	10.2	2½	6	3.4	10.5	60	3.7	10.4	42.9
		<1.0	8.5		18	1.4	9.4		1.8	7.9	
New Plymouth brown loam	67	1.1	8.1	2½	5	3.1	8.3				42.2
		<1.0	7.6		17	1.3	7.3				
Pongakawa shallow peaty loam	107f	3.7	7.3	2½	3	3.2	7.5	20	5.4	7.2	39.9
Moumahaki sandy loam	117	1.7	10.4	2½	17	3.6	9.9				838.7
		1.2	10.1	2½	13	2.0	9.8				
										TOTAL	1255.2

SOUTH ISLAND

Motukarara sandy loam, weakly saline phase		2.7	9.0	2½	30	3.2	9.0	60	2.7	7.7	
		5.1	7.4		18	5.5	7.3		6.0	6.6	

† For North Island samples the soil names and numbers are those quoted in Soil Bureau Bulletin No. 5. Names in brackets following the name of the set, for North Island, are soils recognised in more detailed surveys.

* Soil names for the South Island general survey are provisional and in some cases may be altered when the survey is published. (.....)* indicates that a name has not been allotted and in such cases the texture is given and the district of origin shown in brackets after the texture. (Moutere)* indicates district but name not definitely allotted to soil.

TABLE 4. RESULTS FROM FIELD TOPDRESSING TRIALS. SOILS FROM WHICH PASTURE SAMPLES CONTAINED LESS THAN 3 P.P.M. MO. AFTER TOPDRESSING

NORTH ISLAND†

Soil†	Soil No.	Control Plot		Mo Topdressing	Sample Months after Topdressing	Molybdenum Plot		Lime Topdressing	Molybdenum plus Lime Plot		Area 000 Acres
		Mo p.p.m.	Cu p.p.m.	oz./ac.		Mo p.p.m.	Cu p.p.m.	cwt./ac.	Mo p.p.m.	Cu p.p.m.	
Waipunga silt loam	1a	1.3	10.2	2½	19	1.5	10.6				17.4
Motatau clay	7a			1	6			20	<1.0	8.0	12.0
Waipukurau sandy loam	9b	<1.0	9.0	2½	3	<1.0	7.5	60	<1.0	8.0	12.9
Tokomaru silt loam	13	<1.0	6.3	2½	8	1.3	6.3	20	1.3	7.2	57.7
Milson silt loam	13a	<1.0	8.1	2½	19	<1.0	8.9	40	<1.0	8.9	30.7
Halcombe silt loam, hill soils	13bH	<1.0	6.1	2½	14	1.2	6.8	20	1.7	6.0	30.0
Ohinepanea sand	14c	2.2	7.9	2½	1	4.3	8.4	10	4.6	8.7	15.2
		<1.0	6.6		13	<1.0	6.0		1.4	6.2	
Taupo shallow sandy silt	18a	1.0	14.1	2½	16	1.4	15.9				65.1
Patea sand	23	1.2	5.5	2	2	2.6	5.0	15	3.2	5.4	130.0
		<1.0	5.1	2	15	1.9	5.2				
Patea set (Himatangi sand)	23	<1.0	9.0	2½	17	<1.0	12.2	5	1.1	8.6	
Whananaki set (Pukepuke brown sandy loam)	23b	<1.0	10.0	2½	14	<1.0	9.7	5	1.0	7.8	5.0
Marsden set	23c	2.1	2.8	2½	12	2.2	2.8	20 basic			3.0
Red Hill set	24a	1.0	6.7	2½	14	<1.0	6.4	20	1.9	7.7	62.5
Horea set (average of 5 series)	24d	<1.0	10.3	2½	8	<1.0	9.3	5	1.1	11.4	1.7
Horea set, hill soils	24dH	<1.0	8.0	2½	19	<1.0	9.1	20	<1.0	8.8	18.8
Wanstead clay loam	25a	<1.0	6.4	2½	17	1.5	6.4				57.3
Mangatea set, hill soils	25H	<1.0	8.3	2½	19	<1.0	8.6	60	1.4	5.6	167.0
Atua silt loam	29	<1.0	5.1	2½	17	1.8	6.2				87.6
Mangaotaki set, hill soils	29aH	<1.0	6.0	2½	3	<1.0	7.4				66.0
Korokoro set (Judgeford silt loam, hill soils)	35bH	<1.0	7.7	2½	13	<1.0	6.0				5.0
Marua clay loam, hill soils	35H	<1.0	7.4	2½	10	1.1	10.8	20	<1.0	7.5	290.0
Tauwhare sandy loam, hill soils	44eH	<1.0	7.2	2½	3	<1.0	7.2	20	1.0	6.9	21.2
Waikare clay	45	<1.0	12.5	2½	13	<1.0	12.0		<1.0	10.2	162.0
Waikare clay, hill soils	45H	<1.0	6.1	2½	7	1.6	13.6				29.7
Maungatawhiri fine sandy loam	46d	<1.0	7.3	3	6	<1.0	7.1				5.7
Maungatawhiri fine sandy loam, hill soils	46dH	<1.0	5.2	0.7	7	<1.0	6.3	20	1.7	6.0	19.0
Hangawera set, hill soils	46eH	<1.0	6.0	¾	6	1.5	6.1	20	1.1	7.2	19.9
Te Kuiti sandy silt loam	60a	1.4	8.0	2½	20	1.4	7.9	60	2.6	7.8	9.0
Aria silt loam	60b	1.2	7.4	2½	20	1.2	7.4	60	2.3	9.0	25.7
Te Auku set	61c	<1.0	9.8	2½	19	<1.0	8.9	20	<1.0	9.4	1.5
Ohakune silt loam, hill soils	65H	<1.0	6.9	2½	17	1.6	7.8		<1.0	7.7	38.0
Westmere silt loam	66d	<1.0	9.0	2½	19	<1.0	9.3		1.4	8.9	29.1

(Table 4 continued)

Soil†	Soil No.	Control Plot		Mo Top-dressing	Sample Months after Top-dressing	Molybdenum Plot		Lime Top-dressing	Molybdenum plus Lime Plot		Area 000 Acres
		Mo p.p.m.	Cu p.p.m.	oz./ac.		Mo p.p.m.	Cu p.p.m.	cwt./ac.	Mo p.p.m.	Cu p.p.m.	
New Plymouth sandy loam, hill soils	67bH	<1.0	7.7	2½	16	1.5	8.2	40	1.5	9.4	49.7
Stratford sand	68	<1.0	6.9	2½	12	1.3	8.3		1.5	7.4	86.7
Takapau silt loam	75	<1.0	8.4	2½	18	<1.0	10.4	60	2.5	9.5	102.0
Levin silt loam	76	1.7	6.4	2½	7	1.8	6.6				15.7
Kiwitea set (Belmont silt loam) (Average of 2 series)	76a	<1.0	7.0	2½	14	<1.0	7.9				10.0
Kiwitea loam, hill soils	76aH	<1.0	5.8	2½	16	<1.0	5.8				55.5
Tahuna clay loam	84d			2½	29	2.0	8.2				10.4
Matamau heavy silt loam, hill soils	77bH	<1.0	11.0	2½	18	<1.0	5.8	60	<1.0	5.8	64.2
Dannevirke silt loam	78b	<1.0	9.0	2½	7	1.1	9.3	60	1.4	8.2	36.5
Churchill set	86a	<1.0	11.0	2½	2	<1.0	5.3				16.8
Pakotai clay	90c	<1.0	8.7	2	5	<1.0	7.4				19.0
Kerikeri friable clay	96a	<1.0	6.2	1	5	2.6	6.5				7.5
Rahotu loam	100b	<1.0	7.8	2½	8	2.6	8.5				15.1
Kaitaia clay loam	101b	<1.0	8.3	1	1	<1.0	9.1		<1.0	9.1	16.6
Bluff loam	113	1.2	5.0	2½	2	2.0	5.8	60	2.5	6.1	25.7
Whangaehu set	114	<1.0	4.8	2½	3	<1.0	4.7				147.0
Pohangina set	118a										89.9
Whangamomona silt loam	116	<1.0	8.8	2½	4	<1.0	8.2				447.0
Whangamomona complex	116a	<1.0	7.6	2½	17	<1.0	7.4				182.3
Makara stony loam	122	<1.0	10.1	2½	14	<1.0	9.4	5	<1.0	9.4	275.1
Moeatoa set	122a			1.1	1	<1.0	8.3				62.4
Te Ranga set (average of 2 series)	122b	<1.0	7.4	2½	14	1.5	9.2	20	2.8	8.5	317.4
Ruahine silt loam	124	1.3	7.0	2½	5	1.7	6.0	60	1.7	7.2	643.4
Kaweka sandy loam	125	<1.0	7.3	2½	14	1.5	6.4				402.7
										TOTAL	4677.6
SOUTH ISLAND											
Aparima silt loam		<1.0	5.4	2½	30	<1.0	6.1				
Ashley silt loam		<1.0	8.6	2½	14	<1.0	9.5	60	1.7	8.8	
Blackstone stony loam (.....)* hill soils		<1.0	9.3	2½	15	<1.0	7.3	20	<1.0	7.4	
(Catlins district)		<1.0	5.8	2½	23	<1.0	7.6	10	1.4	6.7	
Chertsey shallow silt loam		<1.0	8.7	2½	17	<1.0	8.1	60	1.4	7.0	
Claremont silt loam		<1.0	10.2	2½	18	<1.0	10.0	60	1.1	9.6	
Clydevale silt loam		<1.0	6.9	2½	15	<1.0	6.5				
Eyre stony silt loam (average of 3 sets)		<1.0	6.6	2½	15	<1.0	6.6	48	<1.0	6.4	
Hari Hari fine sandy loam (.....)* silt loam		2.9	8.3	2½	15	1.0	9.3	40	1.0	6.9	
(Hawarden district)		<1.0	4.1	2½	7	<1.0	4.8	40	1.0	4.6	
Hokitika gravelly sandy loam		2.9	9.1	2½	15	1.5	7.5	40	1.2	7.7	
Glasnevin shallow sandy loam		<1.0	5.1	2½	8	<1.0	4.6	40	1.2	4.4	

(Table 4 continued)

Soil†	Soil No.	Control Plot		Mo Top-dressing	Sample Months after Top-dressing	Molybdenum Plot		Lime Top-dressing	Molybdenum plus Lime Plot		Area 000 Acres
		Mo p.p.m.	Cu p.p.m.	oz./ac.		Mo p.p.m.	Cu p.p.m.	cwt./ac.	Mo p.p.m.	Cu p.p.m.	
Glenroy silt loam (easy rolling phase)		<1.0	5.5	2½	14	<1.0	5.7	60	<1.0	5.7	
Jordan silt loam (average of 2 series)		<1.0	6.6	2½	18	<1.0	7.7	60	1.0	6.6	
Kaiwera hill soils		<1.0	6.9	2½	23	<1.0	6.7	20	1.1	23.9	
Kaiwera silt loam		<1.0	7.1	2½	20	<1.0	7.6	—			
Kakahu silt loam		<1.0	7.4	2½	15	<1.0	8.4	60	2.3	7.0	
Karitane silt loam		<1.0	7.1	2½	3	<1.0	6.1	60	<1.0	6.4	
Lismore very stony silt loam (average of 5 series)		<1.0	7.2	2½	15	1.0	7.1	60	1.1	6.2	
Lismore stony silt loam (average of 4 series)		<1.0	6.0	2½	16	<1.0	5.9	60	1.0	4.9	
Lyndhurst silt loam		<1.0	8.5	2½	17	1.1	7.8	60	2.0	7.8	
Mayfield silt loam		<1.0	5.6	2½	30	1.0	4.5	45	1.6	6.2	
Mokotua silt loam (average of 2 series)		<1.0	6.3	1	33	1.0	5.9	—			
(Moutere)* clay (average of 2 series)		<1.0	4.4	2½	17	<1.0	5.4	60	<1.0	5.8	
(Moutere)* gravel		<1.0	7.9	2½	20	<1.0	6.3	60	1.1	5.5	
Omaka gravelly loam		<1.0	9.3	2½	9	<1.0	8.1	20	<1.0	5.8	
Opuha hill soils		<1.0	3.4	5	16	1.8	4.8	40 + 5	1.6	4.8	
Opuha silt loam (average of 4 series)		<1.0	7.6	2½	20	<1.0	8.5	60	<1.0	7.6	
Opuha hill soils		<1.0	4.7	2	6	1.2	4.2	60	1.6	4.6	
Oxford silt loam		<1.0	11.8	2½	15	2.2	11.7	40	1.1	9.9	
Paparua stony sandy loam		<1.0	5.9	2½	14	<1.0	5.9	60	<1.0	6.0	
Barrhill silt loam		1.0	6.8	2½	13	<1.0	7.1	60	1.5	7.6	
Ranfurly stony loam		<1.0	7.4	2½	16	<1.0	7.6	20	1.1	8.2	
Ruapuna very stony silt loam (average of 2 series)		<1.0	7.8	2½	13	<1.0	7.1	60	1.5	6.4	
(.....)* clay loam (Scargill district)		<1.0	4.8	2½	15	1.1	4.9	—			
Wakanui silt loam		<1.0	7.9	2½	17	<1.0	9.1	60	<1.0	8.6	
Takahe loam		<1.0	6.6	3	18	1.0	6.8	—			
Tasman silt loam		<1.0	6.8	2½	14	1.2	6.9	60	1.4	7.0	
Tautuka silt loam		1.8	8.4	2½	28	1.3	9.2	—			
Te Houka silt loam		<1.0	8.1	2½	13	<1.0	6.9	40	<1.0	6.8	
Templeton silt loam		<1.0	9.9	2½	15	1.0	9.5	60	1.4	9.0	
Templeton silt loam		1.0	5.8	5	16	1.6	6.0	60 basic			
Temuka silt loam (average of 4 series)		<1.0	8.0	2½	17	1.0	8.4	60	1.0	8.2	
Timaru silt loam (average of 2 series)		<1.0	6.8	2	5	1.4	6.5	40	1.2	5.5	
Waimakariri silt loam		<1.0	7.8	2½	18	<1.0	8.2	60	1.6	7.8	
Warepa silt loam		<1.0	7.7	2½	28	<1.0	7.8	60	<1.0	7.0	
Wangaloa stony sandy loam and clay loam		<1.0	10.8	2½	13	<1.0	8.5	60	<1.0	9.7	
Wharetoa silt loam		1.3	8.0	2½	14	1.4	9.8	—			

†

(See footnotes on Table 3)

*

show molybdenum and copper contents of pasture sample from control plot, the rate of molybdate application in topdressed plots, the time after topdressing when samples were taken, the molybdenum and copper contents of pasture from the plot which received molybdate only, the rate of lime application for limed plots, and the molybdenum and copper contents of plots which received lime plus molybdate. Where there was more than one series of plots from one soil, the results have been averaged, and when samples were taken in two successive years from the same plots both sets of results are given. For North Island samples, an approximate area for each soil set is shown and this was arrived at by the method previously described[5].

The most important feature of the tables is the high proportion of North Island soils in which molybdenum in the topdressed pasture exceeded the arbitrarily fixed safe level. Of 64 North Island soils examined, 8 were in this group. One of these was Pongakawa shallow peaty loam on which pasture contained more than 3 p.p.m. molybdenum before topdressing and this soil is therefore not included in the discussion which follows.

The area covered by the 64 soils is approximately 6.0 million acres; the area of 7 highly responsive soils is approximately 1.3 million acres or 20% of the total area of the 64 soils examined. The response is moreover not a short-term one for in five of the soils, Tarawera gravel, Marton loam, Moumahaki sandy loam, Te Kopuru sand (when lime was used) and the Rissington set (when lime was used) one topdressing of 2 or 2½ oz. sodium molybdate per acre produced a rise to above 3 p.p.m. molybdenum in pasture which persisted beyond 12 months. On the other hand, in New Plymouth brown loam and Ohakune silt loam the increase had disappeared some time between 6 and 18 months after topdressing, and the effect of topdressing on these two soils was therefore much less persistent.

South Island soils were in marked contrast since none of the 50 soils examined showed a response in pasture molybdenum that was regarded as high.

For some of both North and South Island trials, the time intervals between topdressing and sampling were over 12 months and a temporary rise in pasture molybdenum would not have been detected. The effect of 1 ton of lime on Pongakawa shallow peaty loam was to raise the molybdenum content of the pasture from 3.2 p.p.m. to 5.4 p.p.m.

Effect of Cobalt Topdressing on Molybdenum Content of Pasture

A report by Mitchell *et al.*[7] that cobalt topdressing will increase the molybdenum content of pasture was investigated by Watson[8] and not confirmed.

Because of the extensive use of cobalt in New Zealand it was felt desirable to take the opportunity for further examination of this question when pasture samples from a cobalt topdressing trial on Otapiri silt loam in Southland were made available by Mr. E. D. Andrews. Samples from six plots collected on six occasions were analysed and the fertilizer treatments, dates of sampling, and results for molybdenum are shown in Table 5. The topdressings applied were as follows:

Cobalt:

Cobalt sulphate, $CoSO_4.7H_2O$ was used.

The 5 oz. per acre rate was applied on 20 April 1950, 10 May 1951, and 24 April 1952.

The 10 oz. per acre rate was applied on 20 April 1950 and 24 April 1952.

Lime:

Applications to plots which received lime were 4 tons carbonate of lime per acre on 20 April 1950, and 2 tons slaked lime per acre on 21 May 1952. On 20 April 1951 the soil pH of control plots was 6.5 and of lime plot was 7.1.

TABLE 5. Molybdenum (p.p.m in D.M.) in Pastures Topdressed with Cobalt Sulphate

Date of Sampling	4.10.51	7.12.51	13.2.52	6.11.52	15.12.52	25.3.53
Control	1.7	1.4	1.3	1.3	1.0	1.1
5 oz. Co	1.6	1.1	1.5	1.1	1.3	1.4
10 oz. Co	1.7	1.3	1.4	1.4	1.3	1.4
Control + lime	1.5	1.3	1.7	1.1	1.0	1.1
5 oz. Co + lime	2.3	1.1	1.6	1.2	1.6	1.3
10 oz. Co + lime	2.3	1.1	1.4	1.6	1.8	1.1

There was no effect on molybdenum content of pasture grown on Otapiri silt loam from either cobalt sulphate or cobalt plus lime topdressings. Copper contents were similarly unaffected but for clarity of presentation the figures have not been included.

Discussion

It is clear that on some soils even very small applications of molybdate as a fertilizer produce a marked increase in molybdenum content of pasture and that with increasing rates the response is greater, approximately in proportion to the amount applied. This has been shown in the present paper for Heretaunga silt loam and for Warepa silt loam (on loess with phonolite) and was previously reported by the same writers for a peat soil of the Hauraki Plains[9]. The effect moreover is very persistent on some soils. On Heretaunga mottled silt loam one topdressing of 1 oz. ammonium molybdate showed a measurable effect and 2 oz. and 4 oz. showed marked effects 18 months after the topdressing was applied, and on Himatangi sand three topdressings each of 2 oz. ammonium molybdate within a period of 17 months produced pasture containing 5.4 p.p.m. molybdenum, or 10 times the content in untreated pasture, 31 months after the last topdressing.

That not all soils are equally responsive to molybdate is evident from Figs. 1 to 4. Heretaunga silt loam and Himatangi sand are very responsive and Warepa silt loam (on loess with phonolite) much less so. A single topdressing of 2 oz. ammonium molybdate per acre on Heretaunga mottled silt loam produced about the same effect as 9.84 oz. sodium molybdate per acre on Warepa silt loam (on loess with phonolite). Differences in response are further illustrated in Tables 3 and 4 which list the results for single samples taken at random intervals of time after a single topdressing. On 7 of 64 North Island soils studied there was an abnormally high response to 2 or 2½ oz. sodium molybdate per acre which is the rate usually recommended on commercial farms. These 7 soils cover 20 per cent of the area covered by the 64 North Island soils. In contrast, on none of 50 South Island soils examined was there a similar high response.

It is obvious that soil is an important factor governing the result from molybdate topdressing and one that must be carefully considered before embarking on a programme of topdressing. Erroneous use of molybdate might do prolonged harm because the persistent effect from a single large or repeated small topdressings on some soils may keep pasture molybdenum abnormally high for periods that extend to years.

The results in this paper and in previous publications give some guide on the question whether a soil is safe or suitable for molybdate topdressing. The 7 soils mentioned above are regarded as unsafe for topdressing at rates of 2 oz. molybdate per acre. The total area of these soils is 1.3 million acres. It was previously shown[5] that 52 North Island soils, covering 4.2 million acres, and peat[10] covering 0.3 million acres grow pastures high in molybdenum without any molybdate topdressing. There is thus about 5½ million acres of North Island pasture land shown to be naturally high in molybdenum or to respond abnormally to molybdate topdressing. The total area of the North Island covered in the surveys mentioned is 12 million acres, and of this nearly 50% could not be topdressed with molybdates without some possibility of harm to grazing stock: a matter that merits very great care when the question of molybdate topdressing is considered.

The areas of the different South Island soils have not been computed so discussion in the same terms cannot be applied. However of 101 soils examined 13 were found naturally high in molybdenum[5] and of 50 soils topdressed and discussed in this paper none reacted by producing pasture of abnormally high molybdenum content. It would appear that risks from using molybdate topdressings exist on some regions of the South Island also but the areas involved are probably not so extensive as in the North Island. In both islands there are small areas of copper-deficient pastures[5] and these constitute a hazard for molybdate topdressing since low pasture copper renders grazing stock more susceptible to increased molybdenum in the pasture.

The points discussed above are related to the large areas of the soils named in this and in a previous paper[5] which should not be topdressed with molybdates, but they have no relevance to the equally large areas on which molybdate could safely be used if it is desirable for pasture improvement.

Two other aspects in the present paper merit some discussion. The difference in response of pasture molybdenum to the same rate of molybdate topdressing on different soils, points clearly to the misinterpretations that might arise in improperly designed experiments to determine the effect of molybdate topdressing on the health of grazing stock. An experiment carried out on a soil which is not responsive to molybdate topdressing might show that certain levels of molybdate application had no effect on grazing stock whereas if the conclusions were applied without further test to a responsive soil the reverse could be the case. It is abundantly clear that no such experiment should be judged only on the amount of molybdate used as topdressing but should be judged also and with major emphasis on the amount of molybdenum that gets into the pasture as a result of the topdressing.

A transfer of molybdenum from topdressed to control plots by sheep employed to graze these plots was suggested from Experiment 2. This might at first thought appear unlikely but consideration shows that appreciable transfer did occur. The ewes which grazed the plot enclosure were drawn from a surrounding paddock which itself had been topdressed with molybdate so as to keep the pasture content of molybdenum at about 6 p.p.m. and the average of the molybdenum contents of the topdressed and control areas of the plot enclosure was also about 6 p.p.m. The ewes were confined to the plot enclosure during the grazing period but came in with their alimentary tracts filled with ingesta containing about 6 p.p.m. molybdenum in dry matter and, for the whole grazing time, spread excreta derived from fodder containing 6 p.p.m. molybdenum. The plot enclosure and the surrounding paddock had been fertilized and managed in closely similar way and the paddock carried 6 ewes per acre, so the pasture production on the plot enclosure could be presumed to support 6 ewes per acre throughout the year. Six ewes eat about 10 kg. dry matter a day, and most of the ingested molybdenum is excreted. In this experiment, therefore, the daily return of molybdenum to pasture in sheep's excreta was about 60 mg. per acre during periods of good growth of pasture, and less in dry and cold parts of the year when pasture production is lower. A reasonable estimate of the daily average throughout the year is 40 mg. molybdenum which is equivalent to 1 oz. ammonium molybdate in a year. For the soil on which the experiment was carried out 1 oz. ammonium moylbdate per annum maintained the pasture at about 3 p.p.m. and the molybdenum level in control plots was what would be expected from this rate of topdressing. This discussion also points to a possible source of error when a small untopdressed area is kept as an untopdressed control and is grazed by animals from a surrounding large area topdressed with molybdenum. The ready transfer of molybdenum could prevent the control area representing a truly untopdressed area.

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RUMEN STUDIES IN SHEEP

II. A COMPARISON BETWEEN RUMEN MICROBIAL END-PRODUCTS IN THRIFTY AND ILL-THRIFTY HOGGETS

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Summary

1. A comparison has been made between the ruminal concentrations of ammonia, volatile fatty acids, protein, and free bacteria in six free-grazing hoggets on dairy-farm pastures and six on sheep-farm pastures. Intakes of herbage were measured concurrently.
2. During the autumn, hoggets on the dairy farm grew at an average of 2.5 lb. per week. At the same time those on the sheep farm showed typical ill-thrift; they grew slowly or lost weight, and two deaths occurred. Internal parasites and rickets were excluded as causes of ill-thrift.
3. Significant though small differences between the groups in volatile fatty acids and ammonia levels were found at the time of ill-thrift. The ratio of acetic to propionic acid was lower in the dairy-farm group. Levels of protein nitrogen were considerably lower on the sheep farm and remained so until normal growth rates were resumed.
4. No gross differences in ruminal micro-organisms were observed.
5. Feed intake during the time of ill-thrift averaged 900 g/day digestible organic matter for the dairy hoggets and 580 g/day for the sheep farm group.

Introduction

The disease in New Zealand known as "hogget ill-thrift" has been described by Clarke and Filmer[1]. From many field studies conducted to date it appears possible that the problem is nutritional. A trial was therefore designed to see if any differences in rumen activity could be detected between thrifty and ill-thrifty animals using the techniques previously detailed[2].

Experimental

Field Work

Twelve wether hoggets, all between 50 and 60 lb. live weight, were divided into two equal groups on 27 January 1954. One group (Group D, sheep Nos. 1–6) was grazed on dairy pastures, where good growth rates were expected, and the other (Group S, sheep Nos. 7-12) on sheep pastures where ill-thrift had occurred during the two previous seasons.

The dairy pasture was partly on Horotiu sandy loam and partly on Te Kowhai clay loam. During the previous 15 years it had been stocked with dairy cattle and no sheep had been on the area. The sheep area was on Te Kowhai clay loam and sloped gently to a corner which remained moist during the summer, promoting a strong growth of paspalum. Apart from the almost complete absence of paspalum on the dairy, the two pastures were similar in botanical composition. Both were mixed swards of high productivity, the main species being perennial ryegrass, white clover and Yorkshire fog.

The dairy sheep were shifted every week or fortnight around five 1½–3 acre paddocks, while the sheep farm group were subjected to a five-day rotation over twelve 1 acre paddocks following a mob of 30 hoggets.

Intakes of herbage digestible organic matter (DOM) were measured as an essential part of rumen studies of this kind. Total faeces collections with bags were made over 5 days every second week from 8 February to 30 July 1954, and intakes calculated by the method of Lancaster[3].

Live weights were measured weekly and when possible twice weekly.

All sheep were drenched with 15 g. phenothiazine fortnightly to control internal parasites, and a single massive dose of calciferol on 14 May to control rickets.

Rumen samples (minimum 50 ml.) were taken from all sheep between 1030 and 1130 hours 2–3 times weekly from 9 February to 10 July. This sampling design was chosen in accordance with the findings from preliminary trials[2].

Laboratory Methods

Determinations of pH, volatile fatty acids (VFA), and ammonium nitrogen were made on the ruminal fluid, using methods previously described[2]. During the latter part of the trial, VFA distillates (3–5 samples for each period) were bulked together for each sheep and the proportions of the individual acids determined by gas–liquid chromatography[4]. The n-butyric and iso-butyric fractions were combined and reported together as butyric acid. Formic acid and acids higher than n-butyric were not estimated.

Protein nitrogen (PN) was determined by precipitating with 70% ethyl alcohol, centrifuging, decanting the supernatant liquid, and washing the precipitate into an 8 x 1 in. test tube for Kjeldahl digestion.

Total counts of free bacteria were made by the method of Moir[5]. A differential study of the microflora was carried out on Gram-stained smears made from 1:20 dilution of the rumen fluid and examined under oil immersion with magnification of 1000 ×. A classification of micro-organisms based on that of Moir and Masson[6] was used, and the indices 1, 2, or 3 given for the presence of a type in low, medium, or high proportion of the total numbers for the small organisms, and of the numbers of large genera for *Oscillospira*, Quin's Oval, and *Selenomonas*. These large genera were included as being easily detectable and of possible value as indicators. Fibre parasitism was studied in Gram stains specially prepared from undiluted rumen contents.

RESULTS

Because of the death of two sheep in Group S and other changes during the trial, the data have been grouped into 8 periods. The results are summarized in Table 1, with the exception of the proportions of VFA which are given in Table 2, and the bacteriological results in Table 3.

Growth Rates and Pasture Conditions

Little rain fell in the late summer of 1954 (period 1) and on the dairy only small patches of cocksfoot remained green in the leaf. On the

TABLE 1. COMPARISON OF THRIFTY AND ILL-THRIFTY HOGGETS

Period	Group	No. of Sheep	Pasture Conditions	Live Weight (lb.) Start & End of Period	Live Weight (lb.) Gain/Week	Intake D.O.M. g. day	Digestibility O.M. %	Rumen Analyses pH	Rumen Analyses VFA millimoles %	Rumen Analyses Ammonium N. mg %	Rumen Analyses Protein N. mg %
1											
9 Feb.–2 Mar. (3 weeks)	D	6	Very dry. Little growth	54 ± 5	56 ± 4 + 0.7 ± 0.7	778 ± 193	77	6.1 ± 0.3	11.2 ± 1.6	21.1 ± 4.1	221 ± 67
	S	5	Some growth esp. paspalum	54 ± 4	54 ± 7 0.0 ± 0.9	638 ± 138	76	6.5 ± 0.2	10.6 ± 1.6	19.7 ± 5.1	139 ± 40
			Autumn Rains Started 2nd March								
2	D	6	Sheep fed hay only	56 ± 4	51 ± 4 − 3.2 ± 1.3			7.1 ± 0.2 **	4.6 ± 1.2 **	12.3 ± 3.7 **	56 ± 9 **
3 Mar.–13 Mar. (11 days)	S	5	Good growth esp. paspalum	54 ± 7	49 ± 6 − 3.2 ± 1.3	734 ± 157	76	6.7 ± 0.1	8.8 ± 1.3	25.8 ± 5.7	167 ± 33
			Sheep 10 Died 10th March (Weight 56 lb.)								
3	D	6	Rapid growth esp. ryegrass	51 ± 4	59 ± 5 + 4.0 ± 0.8	889 ± 150 **	81	6.3 ± 0.2	12.3 ± 1.0 **	44.6 ± 5.9 **	231 ± 48
14 Mar.–29 Mar. (2 weeks)	S	5	Good growth esp. paspalum	49 ± 6	50 ± 4 + 0.4 ± 1.2	573 ± 89	80	6.6 ± 0.2	10.1 ± 1.4	38.6 ± 6.6	191 ± 49
			Sheep 10 Replaced 29th March (Weight 67 lb.)								
4	D	6	Rapid growth esp. ryegrass	59 ± 5	73 ± 6 + 3.5 ± 0.6	931 ± 121 **	82	6.4 ± 0.3	11.0 ± 1.5 *	36.1 ± 8.2	304 ± 51 **
30 Mar.–27 Apl. (4 weeks)	S	6	Growth slower, paspalum dominant	50 ± 4	46 ± 8 −1.0 ± 1.2	524 ± 103	81	6.4 ± 0.2	9.3 ± 1.6	33.2 ± 5.9	210 ± 53
			Sheep 12 Died 28th April (Weight 38 lb.) And Replaced (Weight 73 lb.)								
5	D	6	Tending to become rank	73 ± 6	79 ± 6 + 1.7 ± 0.5	915 ± 130 **	82	6.4 ± 0.2	9.9 ± 1.1	29.3 ± 5.5 **	361 ± 51 **
28 Apl.–22 May (3.5 weeks)	S	6	Ryegrass growth, paspalum declining	56 ± 14	57 ± 14 + 0.3 ± 1.0	657 ± 172	81	6.5 ± 0.2	9.8 ± 1.3	36.3 ± 8.5	219 ± 50
			Ill-thrift Clearing Up About This Time								
6	D	6	Short rye-clover, gr'th slow	76 ± 6	89 ± 9 + 1.4 ± 0.6	886 ± 291	84	6.4 ± 0.3	9.1 ± 1.3	34.3 ± 6.8	293 ± 49
23 May–10 July (7 weeks)	S	6	Ryegrass dominant, growth slow	57 ± 14	63 ± 17 + 0.9 ± 0.7	772 ± 148	83	6.4 ± 0.3	9.1 ± 1.2	34.0 ± 7.5	261 ± 50
			Rumen Sampling Terminated								
7	D	6	Growth slow, pastures cut up	89 ± 9	93 ± 7 + 1.3 ± 0.5	852 ± 324	83				
11 July–31 July (3 weeks)	S	6	Ryegrass dominant, growth slow	63 ± 17	65 ± 17 + 0.7 ± 1.4	776 ± 121	82				
			Intake Measurement "S" Group Terminated								
8	D	6	Spring growth	93 ± 7	111 ± 8 + 3.1 ± 0.6	964 ± 174	83				
1 Aug.–8 Sept. (5.5 weeks)	S	5	Spring growth	71 ± 9	89 ± 11 + 2.1 ± 0.6						
			Sheep 10—Period 1	59	56 − 1.0	442	76	6.9 ± 0.1	8.4 ± 1.2	12.5 ± 4.5	116 ± 17

D. Dairy Farm. S. Sheep Farm. * Significant between groups (P 0.05) ** Significant between groups (P 0.01)

TABLE 2. PROPORTIONS OF VOLATILE FATTY ACIDS
(Periods 4, 5, and 6 only)

Period	Group	Percentage Acid (millimoles %)			Ratio of Acids		
		Acetic	Propionic	Butyric	Acetic/ Propionic	Propionic/ Butyric	Acetic/ Butyric
4	D	57.3 ± 3.2	27.1 ± 2.0	15.6 ± 2.0	2.1 ± 0.2	1.8 ± 0.2	3.7 ± 0.9
	S	62.5 ± 4.4	23.5 ± 3.2	14.0 ± 1.9	2.7 ± 0.4	1.7 ± 0.3	4.5 ± 0.7
5	D	56.3 ± 4.4	27.2 ± 2.6	16.3 ± 2.7	2.1 ± 0.3	1.7 ± 0.3	3.6 ± 0.9
	S	59.7 ± 7.2	24.3 ± 3.9	16.0 ± 3.7	2.5 ± 0.7	1.6 ± 0.3	4.0 ± 1.6
6	D	61.8 ± 1.9	24.3 ± 1.6	13.8 ± 1.0	2.6 ± 0.2	1.7 ± 0.2	4.5 ± 0.4
	S	62.8 ± 2.6	23.0 ± 1.4	14.2 ± 1.7	2.8 ± 0.3	1.6 ± 0.2	4.5 ± 0.8

sheep farm, large paddock differences became apparent, and those areas dominated by paspalum showed persistent growth. Live-weight gains in both groups were negligible.

With the start of the autumn rains on 2 March, pastures grew rapidly. Growth on the dairy was dominated by ryegrass and as a precaution against facial eczema the sheep were penned for eight days and offered hay, of which, however, they ate little. The group on the sheep farm was not disturbed.

Sheep 10 died on 10 March and was not replaced until 29 March. Data for this animal during Period 1 are presented separately in Table 1 and Table 3.

From 14 March to 27 April (Periods 3 and 4), pasture growth on the dairy was continuous and rapid, and the animals grew well. On the sheep farm, pasture growth, especially of paspalum, was good, and abundant feed was available at all times, even after grazing by the larger flock. Despite this, the condition of the hoggets deteriorated, three suffered severe weight losses and one of these, No. 12, died on 28 April. Replacement by a hogget that had been running with the group since 29 March was made immediately. During May (Period 5), the dairy pastures became rank and mature because of undergrazing, and pasture growth slowed down with the onset of colder weather. Weight gains were reduced during the winter months and increased again only when the spring grass came away. On the sheep farm, the paspalum gradually gave way to ryegrass. With the hardening of the grass brought about by cold, hogget growth showed slight improvement, but continued to be poor until the spring.

Growth rates of the experimental Group S were comparable throughout with those of the larger group which preceded them in rotation.

Deaths

Post mortem on sheep 10 showed emaciation, slight tracheitis, lung congestion, slight fatty infiltration of the liver and some inflamed areas of the small intestine.

TABLE 3. BACTERIOLOGICAL RESULTS

Period	Group	Total Free Microbial Count No. per cu.mm × 10^6	Proportions of Morphological Types													
			Bacteria										Large Genera			
			Curved rods Gram negative	Straight rods Gram negative	Straight rods Gram positive	Small cocci Gram negative	Large cocci Gram negative	Small cocci Gram positive	Large cocci Gram positive	Spirilla	Sarcinae	*Oscillospira*	Quin's Oval	*Selenomonas*	Fibre Parasitism
Early 1	D	36 ± 7	1	1	—	3	—	—	—	1		1	1	2	Good
	S	47 ± 6	1	1	—	3	1	1	1	—		1	1	2	Good
Late 1	D	25 ± 5	—	—	—	3	—	1	2	—		1	1	2	Good
	S	34 ± 6	—	1	—	3	—	1	1	—		—	1	2	Good
2	D	14 ± 3	—	—	—	3	—	1	1	—		—	1	1	—
	S	41 ± 9	1	—	—	3	—	2	1	—		1	2	2	Good
3	D	39 ± 10	1	—	—	3	—	2	2	—		—	1	—	Good
	S	35 ± 7	1	1	—	3	—	1	1	—		1	1	2	Good
4	D	52 ± 10	1	—	—	3	—	2	1	—	—	1	2	2	Good
	S	48 ± 10	1	—	—	3	—	2	1	—	—	1	1	2	Good
5	D	60 ± 14	1	—	—	3	—	2	1	—		2	2	2	Good
	S	49 ± 10	1	—	—	3	—	2	1	—		2	2	2	Good
6	D	69 ± 11	1	—	—	3	—	2	1	—	—	1	2	2	Good
	S	61 ± 12	1	—	—	3	—	2	1	—	—	2	2	2	Good
Early 1	Sheep 10	40	—	—	—	3	—	1	1	—		—	—	—	Good
Late 1	Sheep 10	29	—	1	—	3	—		1	—		—	1	2	Good

1. Low proportion 2. Medium proportion 3. High proportion

Post mortem on Sheep 12 showed emaciation, subcapsular haemorrhage of the kidney, fatty infiltration of the liver, slight tracheitis and some inflammation of the small intestine.

Sheep 9 lost over 10 lb. during the autumn and remained constant at 35 lb. live weight even in the spring. Post mortem following slaughter on 2 October revealed no abnormality other than extreme emaciation.

These findings are similar to those commonly encountered in animals suffering from ill-thrift.

Intakes

Striking differences in DOM intake between the two groups were recorded during Periods 3, 4, and 5. The sheep-farm hoggets showed a rise in intake to a level not far from that on the dairy during the latter part of the trial coincident with gain in weight (Period 6 and later).

Rumen Analyses

Concentrations of PN, which were low in both groups during the late summer, rose rapidly in Group D during Period 3 and remained high thereafter. Values for PN in Group S, however, continued to be low during the time of ill-thrift, and large differences existed between the groups until Period 6. Ammonia levels varied considerably during the season, but no exceptional values were recorded.

Significant though small differences in VFA between the two groups were obtained during the time of ill-thrift. The acetic/propionic ratio was significantly lower in Group D than in Group S during Periods 4 and 5, but rose to a comparable value in Period 6. No differences were found in the percentage of butyric acid.

Bacterial numbers fell slightly in both groups during the late summer (Period 1). The semi-starvation of Group D in Period 2 caused a further reduction, but an immediate recovery to normal occurred when the animals were released. Concentrations in the two groups during the remainder of the trial were not significantly different, both showing a slight rise in Period 6.

In all cases, Gram stains showed a predominantly Gram-negative flora, composed of a high population of large genera, very large numbers of small Gram-negative cocci and smaller numbers of Gram-positive cocci. Gram-negative curved rods were present in low concentration except in late summer when they disappeared from both groups, returning when the animals had access to fresh pasture growth (Group S—Period 2; Group D—Period 3). *Oscillospira* could not be detected in Group D during Period 2 or even in Period 3 when the group had been at pasture for 2 weeks. However, these sheep all showed excellent growth rates during this latter period. No other differences in morphological types between the two groups were observed. Fibre parasitism was good in both groups during all periods.

DISCUSSION

Until more information is available on the factors influencing the levels of rumen microbial end-products, it is difficult to interpret the results obtained in this trial. A comprehensive range of normal values

has not yet been defined which would enable a distinction to be made between results due to ordinary variation in pasture chemical composition caused by different botanical species and stages of growth and those due to definite rumen dysfunction. More specifically, in an investigation of this nature, it is important to know how far these levels may be correlated with live-weight gain, in order to decide whether, for instance, the low PN found in ill-thrifty animals could have given rise to the disease or was merely a secondary effect due perhaps to inappetance. The differences between groups cannot be regarded as indicative of any radical abnormality in Group S in the aspects studied, but they may nevertheless have been of sufficient magnitude to have brought about different growth rates.

The figures for PN provide a measure of the levels of microbial protein, though microscopic examination suggests that the contamination from plant fragments may be considerable. The differences found between the groups appear to have been due either to the lower crude-protein content of the pasture consumed by Group S compared with Group D or to the lower percentage conversion of plant nitrogen to microbial protein. Although the protein content of paspalum during the autumn is comparatively low[7], the variety of pasture species on the sheep farm would have permitted the sheep to select material of higher quality than random sampling of pastures would have indicated[8, 9]. Using the average value 4.4% nitrogen in the faeces of Group S during Periods 3, 4, and 5, the nitrogen of the feed eaten was calculated (from the formula of Raymond[10]: per cent N in feed = 0.795 X per cent N in ash-free faeces + 0.14) to be 3.5%, which may be considered as well above requirements for hogget growth. The importance of major conversion of plant to microbial protein depends on the pasture composition and on the particular requirements of the animal. Where the pasture is low in quantity or availability in any of the essential amino-acids, bacterial synthesis is indispensible to the host animal. That ruminal protein may have bearing on the ill-thrift is further suggested by the large rise taking place at the time of recovery in growth rate.

The change between Periods 1 and 3 from dry summer pasture to fresh autumn growth was marked on both areas by a very large rise in ruminal ammonia and on the dairy farm from young (Period 3) to more mature (Period 5) growth by a decrease. These differences, associated with plant maturity, represent the relative availability of the plant nitrogen to the rumen flora. Calculation from the work of Repp *et al.*[11] shows that an ammonia equivalent of 500 mg. per 100 ml. is necessary to cause fatal toxicity in an animal with a rumen volume of 4 litres, and therefore no detrimental effect could have resulted from the levels found in this trial.

The difference between the groups in the acetic/propionic acid ratio is of interest, since mainly changes in the acetic/butyric ratio have hitherto been reported[12]. This is likely to be of significance in intermediary metabolism because of the strong glycogenic property of propionic acid, which is not shared by the other acids[13]. The higher proportion of acetic acid in Group S, however, is unlikely to have greatly contributed to the ill-thrift, since the percentage figure was as high in Group D during Period 6, when these sheep were growing at a steady, though reduced rate.

Differences in the production of fermentation products are due directly to differences in the chemical composition of the feed consumed and any change in substrate will be attended by a change in the balance of micro-organisms. As no differences in morphological types were found between the two groups, differences in organisms within these types must have been responsible. Obviously the method used is only qualitative, and since this work has been completed a more quantitative technique has been developed.

It is unlikely that any of the changes in total bacterial numbers, apart from that in Group D during Period 2, were of biological significance.

The heavy fibre parasitism found in all sheep was in strong contrast with the poor degree of attack which is encountered in cobalt-deficient animals[14]. Evidence from VFA levels and digestibility co-efficients (Table 1) also shows that, in all sheep, rumen fermentation of ingested carbohydrate was satisfactory.

It is conceivable that the disparity in intakes between the two groups might in itself have led to the observed differences in rumen concentrations. Further investigations[15] have shown that lowering of intake may produce a fall in VFA (0.74 millimoles per cent per 100 g. DOM). This would largely account for the observed differences between groups during Periods 3 and 4, though differences in chemical composition of the pastures may have exerted an important influence. An increase in the acetic/propionic ratio was also brought about by lowered intake, though not sufficient to account for the differences found in this trial. No effect on pH, PN, ammonia, or free microbial count was produced by lowering of intake.

There was no evidence within groups of association between DOM and live weight, though some indication, in Group S only, of a positive correlation between DOM and live-weight gain. The failure to obtain a correlation may be partly due to the small number of sheep and the calculation of faeces output from 5-day collection periods. However, these errors are not sufficient to account for the very large differences between groups.

Conclusions

The techniques employed have failed to show any relationship between rumen bacteria and ill-thrift, or any failure in the ability of the flora of ill-thrifty animals to break down cellulose. Ruminal protein levels, however, indicate that there may be an impairment in protein metabolism, and further work along these lines is indicated. Lowered appetite has been shown to be a feature of this disease.

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BLACK ROOT-ROT, *Phytophthora cactorum* (Leb. and Cohn) Schroet, OF THE HOP PLANT

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Summary

Field observations and experimental tests at Nelson have shown the Fuggle variety to have good resistance to the disease. Resistance, to a lesser degree, is also possessed by the Bumford and Golding varieties. The Californian variety is highly susceptible.

The hop strain of *Phytophthora cactorum* is capable of fairly uniform growth over pH ranges between 4.7 and 7.4. At pH 8.7 growth was restricted and at pH 3.0 no growth was made.

In soil sterilization tests no chemical gave complete control of the disease. In early tests some degree of control was shown by D.D. (dichloropropene and dichloropropane) and chloropicrin but this was not sustained in later tests. Little or no control was obtained by the use of capsine, Agrosan, potassium permanganate, mercurous chloride plus sodium chloride, formalin, sodium chloride, potassium sulphate, carbon bisulphide, fermate, Shirlan W.S., Cuprox, calcium cyanamide, potassium dichromate, Dithane Z78, Dithane D14, copper sulphate and C.B.P. (chlorobromopropene).

Introduction

With one exception, a garden at Takaka, the growing of hops in New Zealand is confined to the Nelson district. In the early years of the industry the varieties were of English origin, referred to by the growers as "Green Bine" varieties, and comprised chiefly the Fuggle, Golding and Bumford varieties. Early in the century cuttings of an American variety were brought to Nelson from the Russian River Valley, California, and distributed among growers. Under Nelson conditions this variety, which became known as the Californian variety, proved itself a vigorous grower with a high yield of a good type of hop. It quickly replaced the old English varieties.

It is not known when the black root-rot disease of the hop plant first appeared in Nelson gardens, but information from growers indicates that it was shortly after the introduction of the Californian variety. This variety proved so susceptible that many farmers were forced to abandon the growing of hops or revert to the Fuggle, Golding, and Bumford varieties which under field conditions showed resistance to the disease.

Brien (1938) established that the disease was due to the invasion of the plant tissue by *Phytophthora cactorum* (Leb. and Cohn) Schroet.

Symptoms of the Disease

Toward the end of the growing season, in late January or February, generally the first symptom in apparently healthy and vigorous plants is a sudden wilting of leaves on the upper part of the plant. This may or may not be accompanied by a yellowing of the leaf tissue. Wilting of the lower leaves and death of the bines quickly follow. The dead leaves shrivel and blacken but remain attached to the dead bines which similarly become blackened.

Occasionally plants may show early disease symptoms towards the end of November or in December. The growth of these plants is weak, the bines are not as vigorous as those on healthy adjoining plants and the leaves show some mottling of their surfaces.

Although the disease is commonly known as black root-rot, in the majority of cases the primary infection is of the root-stock or crown from which the fungus moves along the roots and runners. Lesions can however first appear on the roots, either at the tips or along their length. A characteristic feature of lesions on roots and runners is the sharp line of demarcation between healthy and diseased tissue.

The primary invasion is of the cortical tissue which becomes dark brown or black in colour. These lesions, which in the majority of cases are soaked with water, completely girdle the roots or runners. The vascular tissue eventually becomes blackened and water-soaked also, although often the wood may be lighter in colour than the blackened cortical tissue.

Isolations from these blackened lesions or rotted tissues readily yield *P. cactorum* although only occasionally is it possible to obtain a pure isolation of the fungus. Secondary fungi, the most common of which are species of *Fusarium, Gliocladium,* and *Trichoderma,* are found as readily as *Phytophthora.*

In spring when the hills are opened prior to pruning, it is possible to detect plants still alive but affected by the fungus. These bear spindly shoots, few in number, in contrast to the many vigorous shoots arising from the rootstocks of healthy plants. If affected plants are lifted and examined they invariably show the characteristic black lesions of the disease.

Over a period of three seasons, observations were made in four hop gardens to note the relation between the number of plants dying during the growing season and the number of replants necessary the following season. Although the number of dead plants never exceeded fifty in any one garden, the number of replants averaged a third of the total number of plants in each garden. The evidence from these observations and from subsequent tests indicates that the majority of deaths take place during the winter months whilst the plants are dormant and the soil is heavy with moisture.

Effect of the pH Value of the Medium on the Growth of *Phytophthora cactorum* in Culture

To test the ability of the hop strain of *Phytophthora* to grow under acid and alkaline conditions, isolates were grown on potato-dextrose agar adjusted to varying pH values by means of N/10 HCl and N/10 NaOH solutions. At each pH value there were three replicates. In all cases the initial inoculum was 10 mm. square and the incubation temperature 23°C. The diameters of the colonies were recorded daily. At pH 3.0 no growth took place, and at pH 4.1 only a trace occurred, but at pH 4.7 the average diameter after 7 days' growth was 71 mm.; at pH 6.0, 73 mm.; at pH 6.4, 76 mm.; at pH 6.8, 78 mm.; at pH 7.4, 75 mm.; and at pH 8.7, 60 mm. The fungus is therefore capable of making good growth over a wide range of pH values. Between pH 4.7 and pH 7.4 the growth rate was fairly uniform, with the best growth occurring at pH 6.8.

TESTS OF VARIETAL SUSCEPTIBILITY

During the 1949-50 season, twenty cuttings of each of the main hop varieties, Californian, Fuggle, Golding, Bumford and Grape, were planted in outdoor soil previously inoculated with *P. cactorum* to a depth of six inches. Before being planted, a piece of the fungus on agar was applied to the freshly cut base of each cutting. In addition, ten cuttings of each variety received a second inoculation to freshly exposed cortical tissue on the side of the cutting. For controls, sterile agar was similarly applied basally to five cuttings, and basally and laterally to five cuttings of each variety. The control cuttings were planted in soil which was not inoculated.

The following season, a further twenty cuttings of the Californian variety and the same number of cuttings of a variety tending to the Golding type, named Golden Cluster, were added to the test. Each cutting was inoculated basally only with *Phytophthora* and planted in inoculated soil. Ten control cuttings of each of these two varieties were grown.

Table 1 sets out the results of these trials.

TABLE 1. SUSCEPTIBILITY OF HOP VARIETIES TO *Phytophthora cactorum*

Variety	Inoculation		Number of Infected Plants
	Basal and Lateral	Basal Only	
Californian	10	—	10
	—	10	9
Grape	10	—	7
	—	10	7
Golding	10	—	7
	—	10	3
Bumford	10	—	4
	—	10	1
Fuggle	10	—	3
	—	10	0
Californian	—	20	19
	—		
Golden Cluster	—	20	14

In the first group of varieties all infected plants died during the 1949-50 season with the exception of one Californian plant, which died the following winter. The highest number of deaths took place among those plants that were doubly inoculated. Of the fifty plants so treated, thirty-one died, whereas of the plants that received a single inoculation only twenty died. The surviving plants and all control plants remained healthy throughout the 1950–51 season. They were examined during the winter of 1951 and no evidence of infection was found.

Of the two varieties tested during the 1950–51 period, 19 Californian and 14 Golden Cluster plants died. The surviving plants were lifted during the winter of 1951. None was infected nor were any of

the control plants. From all dead plants cultures were made and *P. cactorum* was isolated.

Under the conditions of these tests the Fuggle variety showed the greatest resistance to the fungus, followed by Bumford, Golding, Golden Cluster, Grape, and lastly Californian. The trial confirms field experience of the high susceptibility of the Californian variety.

Although Keyworth (1942) has recorded that *P. cactorum* has been isolated from Fuggle and Golding plants in England, the organism does not appear to be dangerously pathogenic there.

APPLICATION OF CHEMICALS TO INFECTED SOIL

A series of trials has been made to test the effectiveness of a number of chemicals as a means of freeing the soil of the fungus. In the first trial, seventy-five kerosene tins were embedded in soil; twenty-five of these were filled with soil from an infected area of a Moutere Valley hop garden, and fifty with steam-sterilized soil. The soil in each tin was then inoculated with small agar squares of mixed cultures of seven isolates of *Phytophthora*. In addition thirty-three tins of steam-sterilized soil were inoculated with a species of *Gliocladium* and two species of *Fusarium*, which also are found in local hop gardens. After an interval of a week to allow the establishment of the fungi the chemicals under test were applied. Two weeks later, three cuttings of the Californian variety per tin were planted in the tins containing soil from a hop garden and four per tin for the steam-sterilized soil. For each chemical, twelve cuttings were grown, with the exception of capsine for which eight cuttings were used. Thirty-two cuttings were grown as control plants —no chemicals were added to the soil in these tins.

The experiment was continued for three seasons. Surviving plants were then examined and final records taken. Cultures were made from all plants. Table 2 summarizes the results of this trial.

No isolations of *Phytophthora* were obtained from those cuttings which made no growth after being planted. Residual toxicity of the chemical in the soil was shown by the relatively high number of cuttings which failed to grow after being planted in soil treated with chloropicrin. The remaining seven plants of this treatment made very poor growth in the early part of the season but improved later, and in subsequent seasons growth was normal. Poor early growth was also shown by cuttings planted in soil treated with Cuprox and with mercurous chloride plus sodium chloride.

The majority of the plants that died did so during the winter months. A total of 25 plants died during the three growing seasons and 87 plants during the two periods when the plants were dormant. This confirms field observations that most deaths due to *Phytophthora* take place during winter.

There was no difference between the number of deaths occuring among plants growing in soil inoculated with *Phytophthora* alone and those growing in soil inoculated with other fungi in addition to *Phytophthora*. The percentage of surviving plants in the first group was 46%, in the second 45%. No significant difference was shown also in the number of deaths of plants growing in soil from a hop garden

TABLE 2. NUMBER AND CONDITION OF SURVIVING PLANTS AFTER CHEMICAL TREATMENT OF SOIL

Type of Soil	Inoculum	Chemical	Rate per tin	Number of Plants	No growth after Planting	Plants Surviving at End of Trial	Condition of Surviving Plants	Percentage of Healthy Plants
Soil from an infected hop garden	*P. cactorum*	D.D.	4 c.c.	12	—	11	Healthy	91
		Capsine	0.25 g.	4	1	2	,,	67
		Chloropicrin	4 c.c.	12	5	4	,,	57
		Formalin	51 c.c.	12	—	8	6 infected 2 healthy	17
		Shirlan W.S.	3 g.	12	—	3	2 infected 1 healthy	8
		Cuprox	13 g.	12	2	1	Infected	—
		Control	—	12	2	3	,,	—
Steam-sterilized soil	*P. cactorum*	Sodium chloride	12 g.	12	1	5	3 infected 2 healthy	18
		Potassium sulphate	12 g.	12	—	7	5 infected 2 healthy	17
		Sodium chloride	6 g.	12	—	2	Infected	—
		Control	—	8	—	4	Healthy	50
	P. cactorum plus other fungi	Potassium permanganate	3 g.	12	—	10	6 infected 4 healthy	33
		Agrosan	3 g.	12	—	4	Healthy	33
		Mercurous chloride plus sodium chloride	0.3 g. 9 g.	12	1	3	,,	27
		Capsine	0.25 g.	4	—	2	1 infected 1 healthy	25
		Carbon bisulphide	4 c.c.	12	1	5	3 infected 2 healthy	18
		Fermate	3 g.	12	—	7	6 infected 1 healthy	8
		Calcium cyanamide	3 g.	12	1	6	Infected	—
		Potassium dichromate	0.5 g.	12	1	1	,,	—
		Control	—	12	—	5	2 infetced 3 healthy	25

and those in steam-sterilized soil. The percentage of surviving plants in the two groupings was 48% and 44% respectively.

None of the chemicals tested completely suppressed *Phytophthora;* little ability to control the disease was shown by carbon bisulphide, sodium chloride, formalin, potassium sulphate, fermate, Shirlan W.S. Cuprox, calcium cyanamide, capsine, potassium permanganate, Agrosan, and mercurous chloride plus sodium chloride. D.D. at the rate of application used gave the most effective control. Some degree of control was also shown by chloropicrin.

Field Trials

Field trials with chloropicrin and D.D. were carried out in three infected hop gardens. Dead plants were removed and cultures made from them to establish *P. cactorum* as the cause of death. The chemicals were applied with a soil injector at a depth of six inches over an area of six square feet at a rate of 4 c.c. per square foot with an additional injection at a depth of twelve inches near the plant site. A fourth garden was added in the year following the commencement of the trials. In this garden and in two of the other gardens calcium cyanamide was included in the tests, the rate of application being approximately 9 tons to the acre. In three gardens each treatment covered 8 plants; in the fourth garden 7 plants were used. Where calcium cyanamide was added to the experiments, additional control plants were grown. Three of the above gardens were dismantled two years after the beginning of the tests. In the fourth garden the experiment continued for a further season. Records for all four gardens are given in Table 3.

TABLE 3. Condition of Plants Following Chemical Treatment of Soil in Infected Hop Gardens

Garden	D.D.		Chloropicrin		Calcium Cyanamide		Control		Duration of Trial
	Healthy	Infected	Healthy	Infected	Healthy	Infected	Healthy	Infected	
A	8	—	6	2	6	2	10	6	2 seasons
B	6	1	1	6	No Trial		—	7	,,
C	8	—	8	—	8	—	6	2	1 season
D	8	—	6	2	5	3	9	7	3 seasons

Chemicals that showed promise in the earlier trials were further tested at the Hop Research Station, Riwaka. Plots consisted of ten plants each, arranged in a Latin square with guard rows between the plots. At each plant site in the plots agar squares of *P. cactorum* were added to the soil to a depth of ten inches. Chloropicrin, D.D., and calcium cyanamide were applied at the same rate and in the same manner as in the above hop gardens. Capsine was applied at the rate of one gallon of a solution of two pints of capsine in twenty gallons of water to each plant site.

After the trial had been in progress for one season further plots were established to test Dithane Z78, sulphur and CBP. (chlorobromopropene). Sulphur (200 mesh) was applied to the surface of the soil at

a rate of 600 lb. per acre, and Dithane Z78, 250 lb. per acre; CBP. was injected into the soil, 4 c.c. each injection, at a depth of six inches, at one foot intervals, with five additional injections by each plant site at a depth of twelve inches.

In the following season, further plots were laid out using copper sulphate, Dithane D14, and borax. Copper sulphate was applied at a rate of 8 oz., Dithane D14 at a concentration of three parts of the chemical to one hundred parts of water, and borax, $\frac{1}{2}$ oz., to each plant site as required.

The results of this trial are summarized in Table 4.

TABLE 4. CONDITION OF HOP PLANTS FOLLOWING CHEMICAL TREATMENT OF SOIL AT THE HOP RESEARCH STATION

Chemical	Number of Plants	Number of Healthy Plants at End of Trial	Percentage of Healthy Plants	Duration of Trial
Chloropicrin	20	15	75	4 seasons
Capsine	20	9	45	,,
D.D.	20	8	40	,,
Calcium cyanamide	20	8	40	,,
Control	40	17	43	,,
C.B.P.	9	9	100	3 seasons
Sulphur	20	17	85	,,
Dithane Z78	10	7	70	,,
Control	20	16	80	,,

No plants died in the copper sulphate, dithane D14 and borax plots nor in three control plots that were maintained for two seasons only.

Although in the earlier trials D.D. showed promise, this promise was not sustained in the test at the Hop Research Station.

The results from these series of tests do not justify the recommendation of any of the chemicals tested as a means of freeing soil of the fungus.

SUGGESTED CONTROL MEASURES

Since the disease is caused by a soil fungus, control measures are not easy to apply. The position is rendered even more difficult in the case of *Humulus lupulus* because the plant is a perennial and the establishment of new hop gardens is an expensive undertaking.

Since in the majority of cases infection of the plant takes place through the root-stock, and invasion of the root tissues follows as the disease progressses, any measures that will tend to reduce this primary infection will be of value and a possible factor in reducing the severity of the disease. When the plants are pruned, bases of bines and runners should be cut back to the root-stock only. As far as practicable the tissue of the crown should not be cut. If any roots are damaged when

the crowns are exposed these should also be cut cleanly away. After pruning, the rootstock should be left exposed to sun and air so that the cut surfaces may heal quickly. Soil should not be dragged back over the crown until healing has been completed.

When removing dead hills, all fragments of plant tissue should be dug out, carried from the garden, and burnt. If left in the soil this material remains as a possible source of infection to new plants.

When replanting or establishing a new garden, cuttings should be taken only from a garden free of the disease. Cuttings should not be taken from apparently healthy plants in infected gardens.

Wherever possible, standing surface water or flowing sub-surface water should be eliminated by drainage.

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THE ACTION OF MOLYBDENUM ON SOME COPPER ENZYMES

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Summary

Copper-containing proteins have been prepared from sheep's hide in an attempt to demonstrate *in vitro* the functions attributed to copper in producing the crimp and pigmentation of wool. One preparation catalysed the aerobic oxidation of L (-) cysteine and the other showed activity towards L (-) tyrosine and D.O.P.A. (β-(3-4-dihydroxyphenyl) alanine). They exhibited several properties of true enzymes, and were inhibited by molybdate. Molybdate was found to influence the catalysis of the oxidation of p-phenylenediamine by the copper-containing protein coeruloplasmin.

Introduction

The association of excess dietary molybdenum with diseases due to copper deficiency in the grazing animal is now well known (Dick and Bull, 1945; Cunningham, 1949, 1954), and it has been demonstrated that copper deficiency in the animal can be induced by the combined result of a high molybdenum intake associated with a diet supplying adequate sulphate (Dick 1953). The effects of molybdenum as such, however, upon the metabolic activity of copper within the animal do not appear to have been investigated. In an attempt to study this aspect of the problem, preparations containing copper proteins have been made from sheep's hide. These have been shown to possess catalytic activity, and the effect of varying amounts of molybdate upon their activities has been examined.

Experimental Procedure

Preparation (a); showing cysteine-oxidase properties. The wool, together with the subcutaneous muscle and fat were trimmed off a piece of fresh sheep's hide. The hide was washed clean in distilled water, the excess water removed, and the hide cut into small pieces, finely minced and transferred to a Waring Blendor. Twice the weight of M/15 phosphate buffer (pH 6.98) was added and the mass homogenized to a fine suspension. The homogenate was centrifuged at 3,000 rev/min. for 15 min. and the supernatant fluid removed by decantation, followed by Seitz filtering through, initially, a coarse pad and, finally, the finest S.B. grade. The clear pale-red solution was dialysed against the same phosphate buffer solution, in the cold, until a constant copper content was reached, all soluble cupric ion being thus eliminated. The dialysed solution was stored in the cold.

Preparation (b); showing tyrosinase properties. A piece of hide from a black sheep was treated in the same manner as the above until the completion of the centrifugation stage. The sedimented fibre mass was then drained free from supernatant fluid and re-homogenized in approximately twice its weight of water. Any large pieces of fibre were discarded and the fine suspension dialysed against water until free from ionic copper.

Preparation (c); Coeruloplasmin. This was prepared from pig serum according to the method of Holmberg and Laurell (1948). The

enzymatic activity of the preparations was followed by means of the Warburg technique, measuring oxygen absorption. The main vessel contained 1 ml. of enzyme preparation together with 1 ml. of either buffer solution or water, and the side arm held the substrate (adjusted to the appropriate pH) in 0.5 ml. of buffer. All reactions were conducted at 25°C.

RESULTS

Preparation (a)

Initial investigations with the cysteine-oxidizing enzyme were made with solutions obtained by water extraction of the homogenate instead of by phosphate buffer. When phosphate buffer was used for the extraction only, and dialysis made against water, a considerable amount of protein was precipitated with a corresponding loss in activity of the preparation. Examination of the fibre re-suspension prepared according to (b) above of a water extract revealed that considerable cysteine oxidase activity still remained on the fibres, and it was thus evident that the use of phosphate buffer instead of water for extraction brings more of this bound enzyme into solution.

A comparison, based upon copper content, of preparation (a) with inorganic cupric ion is shown in Table 1.

TABLE 1. COPPER-CATALYSED OXIDATION OF L-CYSTEINE: COMPARISON OF CUPRIC ION WITH BOUND COPPER

(a)	(Cu) μg/ml.	0.096	0.16	0.18	0.37	0.42	0.68	0.92
(b)	O_2 uptake μl./min./ml.	0.35	0.40	0.56	0.96	0.93	1.39	2.80
	b/a	3.6	2.5	3.1	2.6	2.2	2.1	3.0
(c)	Cu ion μg/ml.	0.2	0.4	1.2	4	20		
(d)	O_2 uptake μl./min./ml.	0.78	1.47	1.94	2.24	3.6		
	d/c	3.9	3.7	1.6	0.56	0.18		

Main vessel: 1 ml. M/15 phosphate buffer pH 6.98 + 1 ml. copper solution. Side arm: 0.5 ml. of cysteine hydrochloride 0.1M (adjusted to pH 6.98) in buffer.

It is evident that at low concentrations the bound copper was more effective in catalysing the oxidation than was ionic copper, but there was a suggestion that at higher concentrations it may have become a more efficient catalyst.

The activity of the (a) preparations was also dependent upon the pH of the solution. When allowance was made for the increasing tendency of cysteine to autoxidize in alkaline solutions, a broad range of maximum activity was found between pH 7 and 8.

Substrate specificity was shown by the preparations in that, while L (-) cysteine was readily oxidized, no activity was shown towards (-) glutathione, L (-) cystine, DL-methionine, L (-) tyrosine, or D.O.P.A. (β- (3-4-dihydroxyphenyl) - alanine).

Fractional precipitation with ammonium sulphate from a water solution of the enzyme brought down most of the activity between 60-80% saturation.

The amount of oxygen required for the oxidation of 1 mole of L (-) cysteine was of the order of 0.2 moles of oxygen, both for cupric-ion- and bound-copper-catalysed oxidations. Since some hydrogen sulphide was also formed in the later stages of the oxidation this was not accurately ascertained.

The catalytic activity was inhibited by various substances, notable among which were those known to have powerful metal-binding properties.

Fig. 1 shows the effects produced by KCN, versene (disodium salt ethlylenediamine tetracetic acid), sodium diethyldithiocarbamate, and sodium iodoacetate. No inhibition was shown by sodium azide or glycine. Boiling, although denaturing the preparation, made little difference to the activity, unless the denatured protein was removed, but putting a water extract of the preparation through a cation-exchange column (IR-100 H), caused denaturation with considerable loss of activity. The most interesting inhibition was, however, shown by molybdenum, added as ammonium molybdate, and depicted in Fig. 2.

It is evident that large amounts of molybdenum greatly inhibited the rate of oxidation of cysteine while relatively small amounts of molybdenum also showed an appreciable retardation. Sulphate showed no effect upon either the inhibitory effect of molybdenum or upon the reaction itself. If molybdenum was added to a solution of preparation (a) in phosphate buffer, and in sufficient quantity to cause appreciable inhibition (1 mg. Mo/ml.), and the solution then dialysed against buffer until free from molybdenum, the activity of the preparation was unaltered. This is an indication that unlike the inhibition produced by KCN, when subsequent dialysis to remove the KCN also removes all the copper from the preparation, the molybdenum did not displace the copper from the protein.

Preparation (b)

Examination of the fibre preparations (b) from a black sheep showed evidence of L (-) tyrosine and D.O.P.A. oxidase activity, while a water extract corresponding to preparation (a) from the hide also showed considerable activity towards L (-) cysteine, but not towards L (-) tyrosine or D.O.P.A. Similar fibre preparations (b) from unpigmented animals revealed no activity towards either L (-) tyrosine or D.O.P.A.

The activity of fibre preparations (b) was inhibited by molybdenum as is evident from Fig. 3, although molybdate forms an orange complex with D.O.P.A.

In an attempt to produce an enzymatic inhibition by molybdenum *in vivo*, a black sheep was fed on lucerne (a diet adequate in sulphate) and given a daily dose of 100 mg. of molybdenum as ammonium molybdate. A piece of hide was removed at the beginning of the experiment, and tested for its activity towards L (-) tyrosine, D.O.P.A., and L (-) cysteine as outlined above. After 22 weeks, when pigment fading in the wool was evident, a further section (approximately 10 g.) of hide

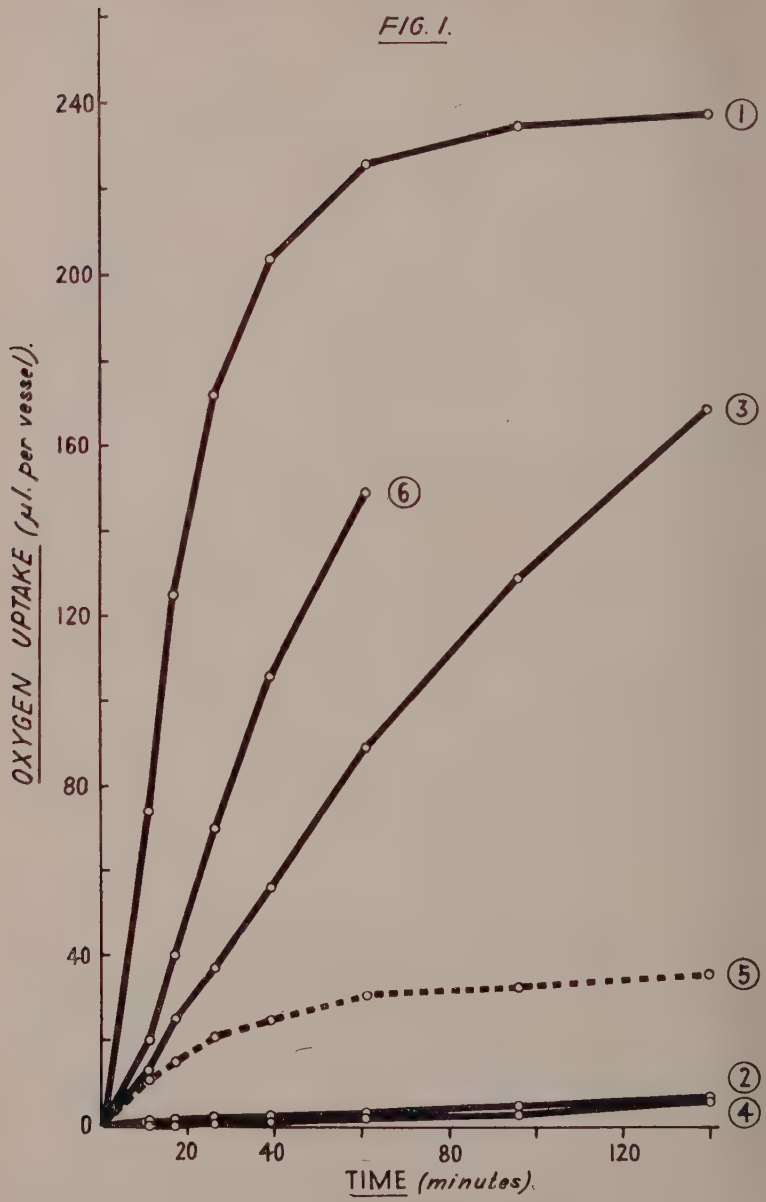

Fig 1.—*Main vessel*: 1 ml. water + 1 ml. buffer extract (preparation a). *Side arm*: 0.5 ml. cysteine hydrochloride 0.1 M (adjusted to pH 6.98) in buffer.

(1) No inhibitor, (2) KCN 5 mg. main vessel, (3) versene 10 mg. main vessel, (4) Sodium diethyldithiocarbamate 5 mg. main vessel, (5) Sodium iodoacetate 10 mg. main vessel, (6) Cation-exchange resin IR - 100 H eluate.

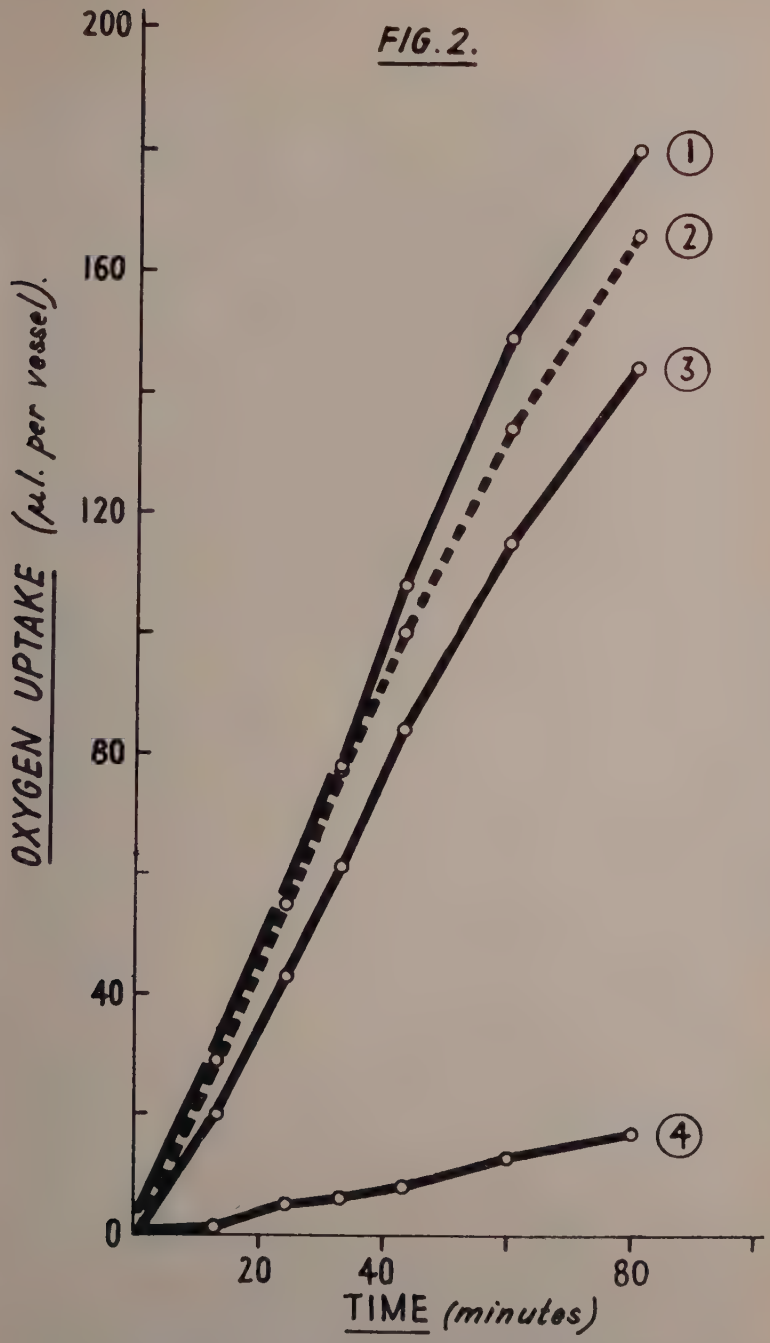

Fig 2.—*Main vessel:* 1 ml. water + 1 ml. buffer extract (preparation a). *Side arm:* 0.5 ml. cysteine hydrochloride 0.1 M (adjusted to pH 6.98) in buffer.
(1) Nil, (2) 0.5 mg. (3) 1.0 mg. (4) 8 mg. Mo in main vessel added as ammonium molybdate.

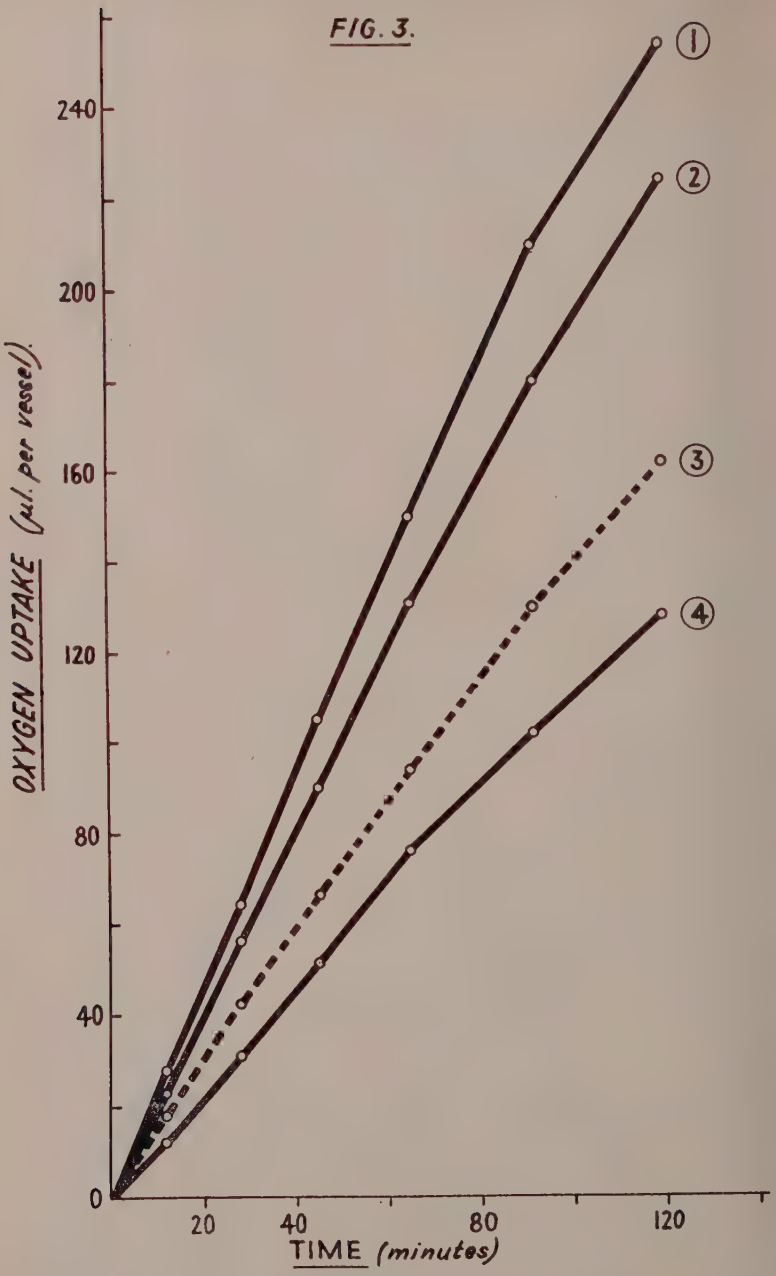

Fig 3.—*Main vessel:* 1 ml. phosphate buffer M/15 pH 6.98 + 1 ml. fibre suspension (preparation b).
Side arm: 0.5 ml. substrate in buffer. Tyrosine M/50 suspension. D.O.P.A. 0.1 M.
(1) Tyrosine, (2) D.O.P.A., (3) D.O.P.A. + 5 mg. Mo in main vessel, (4) Tyrosine + 5 mg. Mo in main vessel.

was removed and again tested as above. The activity was much less than initially, indicative of a lower copper status, but, most important, a crude-fibre suspension showed less activity towards L (-) tyrosine and D.O.P.A. than the same suspension after dialysis. This is outlined in Table 2.

TABLE 2. OXYGEN UPTAKE (μl/min./ml.) OF FIBRE PREPARATIONS FROM A BLACK SHEEP, BEFORE AND AFTER TREATMENT WITH MOLYBDENUM

Substrate	Before	After	
		Not dialysed	Dialysed
Tyrosine	0.92	0.24	0.74
D.O.P.A.	0.82		

Main vessel: 1 ml. M/15 phosphate buffer pH 6.98 + 1 ml. fibre suspension.
Side arm: 0.5 ml. substrate in buffer. Tyrosine M/50 suspension. D.O.P.A. 0.1M.

This was not the case, however, with the activity towards L (-) cysteine, but in view of the powerful catalytic activity of cupric ion, this effect may have been obscured by the large amounts of non-bound copper present in the undialysed preparation. Whether this inhibition was due to the relatively small amount of molybdenum present in the undialysed preparation (0.4 μg/ml.) or to some other inhibitory substance it is not possible to say. The blood molybdenum level of the sheep was 1.9 μg/ml.

Preparation (c)

Coeruloplasmin solutions in water were used to catalyse the oxidation of p-phenylenediamine (p.p.d.) in acetate buffer pH 6.0 as outlined by Holmburg and Laurell (1951).

Molybdate in the range 20 to 2000 μg/ml. of molybdenum was found to influence the rate of the oxidation. Low concentrations caused an acceleration of the reaction rate while higher concentrations initially retarded it. The presence of NaCl greatly enhanced the inhibitory action of molybdenum. At pH 7.0, however, molybdenum showed only an acceleration of the rate of reaction.

DISCUSSION

The examination of the properties of the above preparations suggests that they may contain specific copper-containing enzymes, but, as is the case with other such metal-containing proteins, the designation of a true enzymic character as opposed to a non-specific binding of metal by protein must await further purification and, if possible, preparation in a definite crystalline form.

The dependence of the activity upon the presence of copper is evident from Table 1 and from the loss of activity when KCN was used to remove the copper from the protein fraction. The copper was however not rigidly bound to the protein since it reacted with sodium diethyldithiocarbamate, and moreover prolonged dialysis against glycine (0.1M) solution caused a loss of copper from the preparation. Similarly the inhibition produced by versene was probably due to a complexing of the copper attached to the protein.

The specificity shown towards L(-)cysteine by preparation (a) was however strongly in favour of its enzymatic character. The fact that the tyrosinase activity of preparation (b) was found only in preparations from black sheep and not in those from unpigmented animals also strongly suggests the presence of a specific enzyme in these cases.

The fibre suspension (preparation (b)) was from its nature comparatively crude and showed a tendency to retain the cysteine-oxidizing fraction, possibly by absorption. It is however evident that, in an animal exhibiting pigmentation, this preparation contained a factor responsible for the tyrosinase-like activity.

The effects produced by molybdenum in inhibiting the activity of coeruloplasmin towards p-phenylenediamine are interesting in as much as they support the work done with the two preparations above, but because of the non-physiological significance of the reactions these observations were not further pursued.

The present work thus clearly indicates that molybdenum can have an inhibitory action on some animal copper-containing proteins which show catalytic activity. While the role of molybdenum in depleting the body reserves of copper is undisputed, molybdenum may also interfere with copper function by the direct inhibition of enzymatic activity *in vivo*. This possibility deserves further investigation.

Acknowledgements

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MOLYBDENUM EXCRETION AND RETENTION IN THE SHEEP

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Summary

Ammonium molybdate, dosed to sheep on a low-sulphate diet consisting of chaffed oaten hay, is largely accumulated in the body and is not excreted until a tissue degeneration involving sulphur catabolism occurs. The molybdenum appears to be present in the blood as molybdate. Sheep receiving molybdenum on a diet adequate in sulphate, consisting of chaffed lucerne hay, excrete almost their entire intake of molybdenum, a large proportion being excreted in the urine apparently as molybdate. Renal molybdenum excretion is not related to diuretic activity, but is enhanced by the administration of DL-methionine, sodium maleate, sodium fumarate, and phloridzin to the animal.

Introduction

Since the demonstration of the limiting action of excessive intakes of molybdenum on the utilization of copper by the animal (Dick and Bull, 1945; Comar *et al.*, 1949) the importance of molybdenum in animal metabolism has received increasing attention. However, the examination of copper-deficiency symptoms on pastures containing the normal few parts per million of molybdenum, led other workers (Stewart *et al.* 1946: Green, 1951) to propose the presence of another factor capable of limiting copper storage. A possible correlation of these observations has been proposed by Dick (1953), who showed that molybdenum was able to limit copper storage in the animal, only if adequate amounts of sulphate were present in the diet. Without sulphate, both copper and molybdenum accumulate in the body. The kidney was shown to be an important organ for excretion of the molybdenum. The present work was undertaken to study this dependence of molybdenum excretion upon dietary sulphate.

Experimental Methods

Sheep were chosen for experimentation on the basis of the equivalence of their liver-copper concentrations determined by analysis from biopsy liver samples. They were pen fed on a diet of chaffed lucerne or oaten hay, and were either hoggets or two-tooth wethers. All sheep received a daily dose of ammonium molybdate equivalent to 50 mg. of molybdenum (unless otherwise specified), contained in 25 ml. of water.

Urine was collected from the wethers in a polythene belly-tank, strapped to a harness. Faeces were collected in faeces bag in the normal manner.

Venous blood was collected using oxalate as anticoagulant, and was always withdrawn a specified time (usually 24 hours) after the last dosing.

Molybdenum was estimated by the method of Perrin (1946), with slight modification. The interference produced by the presence of large

amounts of iron was eliminated by keeping all solutions free from oxygen by saturating with carbon dioxide.

Sulphate was estimated by the method of Hawk *et al.* (1947).

Results

Blood containing 5–20 μg./ml. of molybdenum drawn from sheep on the oaten diet, and urine containing approximately 20 μg./ml. of molybdenum collected from sheep on the lucerne diet, were examined to determine the chemical nature of their contained molybdenum. On dialysis against physiological saline, whole blood or corpuscles lost molybdenum, and likewise the separated plasma when dialysed against water also readily lost its entire content of molybdenum. Concentration of the dialysates and examination by paper electrophoresis (acetate buffer pH 6.0), or ion-exchange columns (IR-100H and IR-4B) revealed that all the molybdenum was present as an anion. Similar examination of urine by paper electrophoresis and ion-exchange resins showed that all the molybdenum was present as an anion. Extraction of the concentrated blood dialysates or of the urine with a variety of organic solvents failed to reveal the presence of any extractable organic fraction containing molybdenum. Both the urine and the dialysates gave a phenyl hydrazine test for molybdate (Vogel, 1954). From these tests it was considered that molybdenum was present as an anion in the blood and urine of the experiment sheep. Since the molybdenum dosed to these animals was in the form of molybdate it is the most probable form of the molybdenum in the materials examined.

One of the possible effects of sulphate on molybdenum metabolism is upon the permeability of membranes to molybdenum. Experiments were conducted with red blood cells to determine whether or not sulphate had any influence upon the rate of diffusion of molybdenum through the cell wall. Sedimented, centrifuged corpuscles from a sheep on the oaten diet were agitated for 48 hours at room temperature in saline with and without the addition of sulphate (up to 150 mg/100 ml.). Likewise corpuscles from a non-treated sheep on a lucerne diet and containing <0.01 μg./ml. of Mo were suspended with agitation for 48 hours in saline containing 20 μg./ml. of Mo with and without the addition of sulphate. The results of the experiments indicated that sulphate exerted no influence upon the rate of diffusion of molybdenum. Naturally occurring sulphate in the blood from lucerne-fed sheep likewise exerted no influence upon molybdenum diffusibility. This was tested by separating blood from the two groups of sheep into corpuscles and plasma and resuspending the corpuscles of each group in the plasma of the other. In all cases allowance for residual plasma or suspensory fluid was made by haematocrit estimation of red-cell volume.

The changes in blood molybdenum level for sheep receiving daily doses of molybdenum on a chaffed oaten diet are shown in Table 1.

In sheep dosed 50 mg. Mo/day, there was a sharp rise in blood molybdenum to levels as high as 30 μg/ml. followed after a few weeks by a rapid decline to low levels again. In sheep dosed 10 mg. Mo/day, the blood molybdenum levels were correspondingly lower, and over a comparable period of time no fall was evident. If the sheep were small, blood molybdenum did not reach such high levels as with larger sheep on the same daily intake of molybdenum. Table 1 also shows a

TABLE 1. BLOOD MOLYBDENUM LEVELS AND WEIGHT LOSSES FOR SHEEP ON A CHAFFED OATEN DIET

	Time	Days	0	18	26	33	39	43	49	58	76
(a)	Wgt.	Kg.	25.7	22.3	21.0	21.0	20.8	—	—	18.2	—
	Blood Mo.	μg/ml.	—	0.5	0.5	0.7	1.0	—	—	0.2	—
(b)	Wgt.	Kg.	46.8	44.0	43.0	41.0	39.6	—	—	37.5	—
	Blood Mo.	μg/ml.	—	4.5	5.3	5.6	7.7	—	—	10.0	—
(c)	Wgt.	Kg.	44.7	42.8	41.6	41.0	40.5	—	—	38.5	—
	Blood Mo.	μg/ml.	—	7.0	10.5	15.5	23.5	30.0	20.0	13.0	4.6

(a). (b). Sheep receiving molybdenum at levels of 10 mg./day.
(c) Sheep receiving molybdenum at levels of 50 mg/day.

progressive weight loss for these animals on the above treatment. This weight loss was moreover accompanied by a change in urinary sulphate excretion from levels of 2-5 mg. SO_4/100 ml. to 30–40 mg. SO_4/100 ml. The pH of the urine also changed from pH 6 to pH 8, often with the appearance of large amounts of "triple" phosphates as a sediment in the urine. Consequently, to evaluate the effect of various substances upon the excretion of molybdenum by sheep receiving 50 mg. Mo/day, the criterion of a rising blood molybdenum was selected, and duplication of any effect was always obtained before being considered positive.

The following substances were tested on sheep for their effect upon molybdenum excretion. Neptal, (intramuscular); urea, (40 g./day orally); Diamox, (oral and intravenous); phloridzin, (0.5 g./day subcutaneous); sodium maleate, (1 g./day intraperitoneally); sodium fumarate, (1.5 g./day intraperitoneally); sodium malonate, (1.5 g./day intraperitoneally); sodium citrate, (3 g./day intraperitoneally); DL-methionine, (1.0 g./day intravenously); disodium hydrogen phosphate, (2 g. of P/day orally).

The effect of any substance upon molybdenum excretion was generally seen almost immediately in the urinary output, although any marked alteration in excretion rate was also found to be reflected in a change in blood molybdenum level. Consequently, both 24-hour urinary molybdenum excretion and weekly blood molybdenum levels were followed in each experiment. To overcome natural variations from day to day in urinary excretions, the evaluation of the effect of an administered compound was determined by following the excretion of 4-6 days before and after treatment.

Diuresis, i.e. urinary volume excretion increased by approx. 300%, was produced by the administration of "Neptal" and urea to sheep. "Diamox" (a non-mercurial diuretic) produced only a poor response in the test animals. In no case however was there any increase in the excretion of molybdenum, and in fact in the case of "Neptal" administration a slight fall, due to kidney damage, was experienced.

Phloridzin caused an immediate failure in kidney tubule readsorption of glucose and, after 2–3 days of administration, a rapid increase in urinary molybdenum excretion occurred.

Sodium maleate and fumarate caused an immediate increase in urinary molybdenum excretion, but differed in that maleate also was accompanied by an appreciable diuretic effect.

Sodium malonate, citrate, and phosphate, had no effect upon the excretion of molybdenum.

DL-methionine caused an immediate large increase in molybdenum excretion accompanied by an appreciable fall in blood molybdenum levels. These effects are shown in Fig. 1.

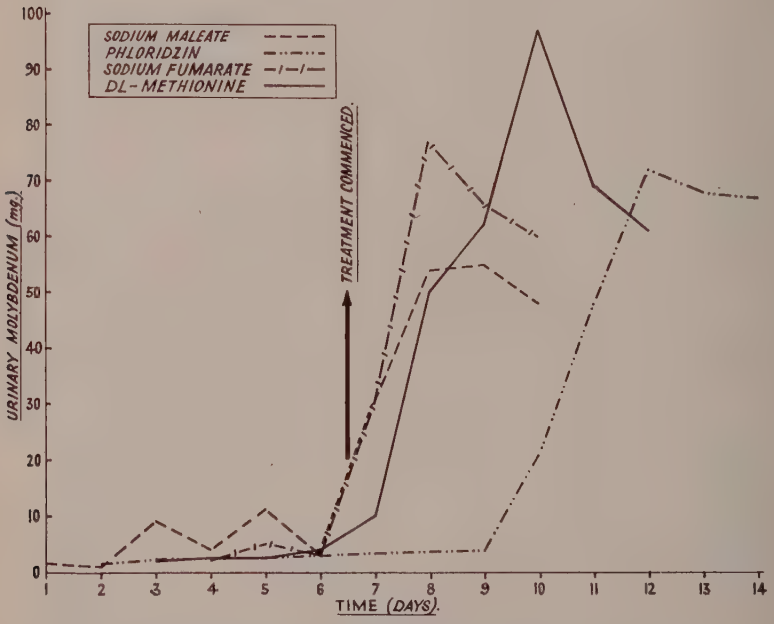

Fig. 1.—Effect of various compounds on the urinary excretion of molybdenum by sheep receiving doses of 50 mg. molybdenum/day. Curve (1) sodium maleate, (2) phloridzin, (3) sodium fumarate, (4) DL-methionine.

Discussion

The examination of the nature of the molybdenum accumulated in the blood of sheep on a low-sulphate diet, and of the excreted urinary molybdenum from sheep on an adequate sulphate intake suggests that in both cases the molybdenum is uncomplexed in any way, and exists in the form of a simple inorganic anion, the most probable form of which is molybdate. The permeability of the red-cell membrane to molybdenum appears to be unaffected by the presence or absence of sulphate as determined *in vitro*. It is however worth noting that whereas the red-cell molybdenum can be readily lost by dialysis over a period of 48 hours, it is not so readily accumulated in this same time. Thus equilibrating red cells with either saline or plasma containing high concentrations of molybdenum does not give the same equilibrium ratio of red-cell molybdenum to plasma or saline molybdenum as exists

naturally in the whole blood of dosed sheep. Thus, in the normal distribution of molybdenum in whole blood, approximately ⅓ is found in the red cells, whilst after 48 hours of equilibration the red cells contain only ⅙th of the total amount of molybdenum present.

The loss of molybdenum previously accumulated in the body of sheep dosed 50 mg./day is apparently associated with a catabolic breakdown of body tissue with the consequent formation of sulphate which when excreted by the kidney also allows the passage in the urine of large amounts of molybdenum. It is possible that this sulphate is derived from the sulphur-containing amino acids of tissue proteins. If the animal is kept under the same conditions for a further period, generally a few weeks, death results and post-mortem examination reveals extensive kidney damage especially to the tubules. An attempt was made to supplement the diet of a sheep, which had reached the climax of its molybdenum storing process, with firstly a fat supplement consisting of olive oil-lanoline 50/50 and then a carbohydrate-enriched (crushed oats) urea supplement (4% of carbohydrate diet). Degeneration however still set in with the consequent fall in blood molybdenum.

Significant differences are to be found in the manner of excretion of molybdenum for sheep on the two diets, and for animals on the oaten diet before and after the climax of molybdenum retention is reached. Thus, on lucerne, sheep were found to excrete approximately 15–20 mg./day of molybdenum in the urine when receiving a daily dose of 50 mg. of molybdenum. For sheep on the oaten diet and also receiving a daily dose of 50 mg. of molybdenum the excretion distribution was approximately urine 5%, faeces 18%, and the balance of the intake retained, while for a daily intake of 10 mg./day of molybdenum 2.5% is excreted in the urine and 38% in the faeces, the balance being retained. After the climax is reached a marked increase in the urinary excretion of molybdenum is found, possibly a consequence of the increased sulphate excretion associated with this change. Thus for a sheep on an intake of 10 mg./day of molybdenum the proportion of molybdenum excreted in the urine had risen to 25% while that in the faeces was 37%, of the daily intake.

It is doubtful whether any of the substances which have been found to increase urinary molybdenum excretion in sheep can be considered comparable to sulphate in their action. Post-mortem examination of the kidney after their use generally revealed extensive damage especially to the tubules as tubulonecrosis and the appearances of many casts. From this viewpoint sodium maleate appeared to be particularly toxic and produced a large diuretic effect as well, whereas sodium fumarate, its isomer, was better tolerated and did not have the same diuretic effect. Malonic and citric acids occur in pasture, and were found to be inactive in the removal of molybdenum.

The powerful action of DL-methionine in causing a large urinary excretion of molybdenum accompanied by a fall in blood molybdenum level is interesting, but could be due solely to its oxidation to sulphate by body enzymes. It is however worth noting that methionine has been found capable of protecting rats from the growth-inhibiting and toxic effects of excessive molybdenum intakes (Gray and Daniel, 1954).

The influence of sulphate upon molybdenum excretion is thus possibly part of the wider field of sulphur detoxication mechanism,

involving such things as the poisoning of body enzymes by heavy metals, and their protection by the introduction of sulphur-containing compounds, eg. B.A.L. (British anti-lewisite). The protective action of the mercaptans on ascorbic acid, heavy-metal-catalysed oxidation is well known, as is the essential role of lipoic acid in cellular metabolism.

Acknowledgements

I am endebted to the Department of Agriculture for the facilities to undertake this investigation and to the New Zealand Defence Scientific Corps for financial assistance.

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USE OF LIME ON FLUE-CURED TOBACCO

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Summary

The use of ground limestone at ½ ton per acre every second year brought about an increase in yield of flue-cured tobacco without any delay in maturity or reduction in quality.

The pH of the soil was raised to an undesirable degree. Exchangeable lime was increased but exchangeable potash and magnesia were scarcely affected.

Soluble ash and lime contents were the only mineral constituents of the cured leaves to be significantly affected. Total reducing sugars and nitrogen contents were not altered by liming. Marked seasonal variations occurred in the chemical composition of the leaves.

Introduction

Lime is widely used in general farming practice in New Zealand to improve the physical condition of the soil, if not as part of the fertilizer programme for a wide range of crops. Because flue-cured tobacco is grown on soils of a sandy nature with a low cation-exchange capacity, and in many ways is grown contrary to generally accepted agricultural practice, it was considered that the lime requirement of the crop warranted investigation. Trials were commenced at the Research Station in 1945–46 and were continued for eight seasons.

Review of Literature

A review of the literature dealing with the use of lime on flue-cured tobacco soils reveals a diversity of opinion. Lutz and Moss[3] at Oxford, N. C., obtained an increase of 252 lb. of leaf per acre and a gain in value of 48 dollars on limed land compared with unlimed, but qualify the results by stating that the lime should be applied in the rotation one to three years ahead of the tobacco or leaf quality will suffer. On the other hand Clark[1] working in Florida reported no differences in yield or quality when the rate of liming was varied to provide the equivalent of 0, 40, 80, and 120 lb. CaO per acre. Garner[2] states that the liming of flue-cured-tobacco soils is not a good practice unless the pH falls below 5.0. Stinson and Murwin[4] in Canada advised against the use of lime on account of delayed maturity and the bringing about of more favourable conditions for black root-rot. Wolf[5] also in North Carolina says the addition of lime appeared to be unfavourable to flue-cured tobacco. Several other workers express no direct opinion on the use of lime, but all agree that the pH of the soil must be closely watched and kept around 5.6.

Soil

The soil on which the trial was carried out is derived from the "Kaiteriteri" series and is classified as "Umukuri" medium sand, 10-12 in. deep, overlying sand and gravel. These soils are chiefly of granite origin, acid in reaction, with a pH of about 5.6. They are naturally low in phosphate and potash, but because tobacco has been

grown on them for many years with liberal applications of phosphatic fertilizer, the phosphate reserve has increased considerably. Deficiencies of magnesium and boron also occur.

Method and Layout

Four treatments were included in the trial:

a. Standard 3-8-8 (N-P-K) tobacco fertilizer. As the phosphate in this was derived from superphosphate it contained an appreciable quantity of calcium.

b. A special 3-8-8 fertilizer containing no calcium. In this the superphosphate and sulphate of ammonia were replaced by ammonium phosphate and the other nitrogenous components adjusted accordingly.

c. Standard fertilizer plus lime.

d. Special fertilizer plus lime.

In 1950–51 a modification was made in the composition of the Standard fertilizer. Up to this time the nitrogen had been provided in equal proportions by nitrate of soda, sulphate of ammonia, and dried blood. As all the nitrogen in the special mixture was in the ammonium form, the mixed nitrogen in the Standard was replaced by a single source of nitrogen, viz. sulphate of ammonia, to bring the composition of the two fertilizers more into line with each other.

The fertilizer was applied at the rate of 1,000 lb. per acre, half at planting time, and half as a side dressing, three weeks later. The lime was ordinary ground limestone applied the first year of the experiment and every second year thereafter at $\frac{1}{2}$ ton per acre. It was broadcast after the spring ploughing and worked in.

The experiment was carried out on the same area each year, i.e. under a system of continuous tobacco culture which is still the practice over the greater portion of the Nelson tobacco area. A cover crop of ryecorn was grown each winter and ploughed under in the spring. The variety of tobacco grown was Harrison's Special.

The experiment was laid out in randomized blocks with five replications. Plots were each six rows of 27 plants. The outside rows and end plants were discarded as guard rows leaving a plot of four rows by 25 plants to be weighed.

Results

Yields covering seven out of eight seasons are given in Table 1. The figures for 1947–48 have been omitted as severe flooding occurred that season.

The two formulations of fertilizer have given almost identical yields. However, over the period of the experiment liming has given a highly significant increase averaging 85 lb. of leaf per acre per season. It is noted that, while the results of liming were somewhat erratic in the earlier seasons, as the experiment progressed the limed plots outyielded the unlimed consistently.

There was no interaction between the liming and the fertilizer mixture. Liming had no consistent effect on the growth or maturity of the crop in the field.

TABLE 1. YIELD OF CURED LEAF IN POUNDS PER ACRE

Treatment		1945–46	1946–47	1948–49	1949–50	1950–51	1951–52	1952–53	Average
Standard fertilizer	(sl)	1566	1494	1184	1402	1485	1240	1657	1433
Standard with lime	(sL)	1582	1482	1227	1456	1619	1321	1812	1500
Special fertilizer	(Sl)	1561	1486	1093	1318	1453	1306	1631	1407
Special with lime	(SL)	1726	1440	1202	1433	1612	1436	1720	1510

Treatment Comparisons

Special fertilizer vs Standard fertilizer	=	—7.78 lb.
Lime vs No lime	=	+85.58 lb.
Interaction	=	+18.36 lb.

Significant differences

5% level	1% level	0.1% level
46.48 lb.	61.18 lb.	78.85 lb.

TABLE 2.

Treatment	Leaf Index				Acre Index			
	1950–51	1951–52	1952–53	Average	1950–51	1951–52	1952–53	Average
sl	382	352	500	411	473	370	690	511
sL	355	387	503	415	479	438	760	559
Sl	383	380	497	422	474	418	675	522
SL	364	377	486	409	488	457	697	547

In Table 2 are given the leaf index and acre index for the last three seasons of the experiment. The figure for leaf index is a measure of overall leaf quality giving recognition to the weight and value of each grade. The acre index takes into account both leaf index and yield per acre. Differences in the leaf index are not significant. There was a tendency for the limed plots to produce a slightly heavier-bodied leaf than the unlimed but this was not reflected in the leaf index. In the acre index any increase in the index figure has been due to the greater yield of the plots receiving lime.

SOIL ANALYSES

During the course of the experiment nine sets of samples of soil have been taken. In the first sets the samples were taken in shallow spits, but the analytical data for these did not vary greatly so they have been calculated to a 0–9 inches basis to correspond to later samples taken at 0–9 inches and 9–18 inch depths. Data for pH value and exchangeable lime (CaO) of 0–9 in. samples are presented in Fig. 1. Dates of samples are given by month and year. The first samples were taken immediately before the first application of ground limestone was

TABLE 3. CHEMICAL DATA FOR SOIL SAMPLES

Treatment	Date of sampling	Depth of sampling inches	Cation-exchange capacity m.e.%	Base Saturation %	pH Value
Standard fertilizer	25.10.45	0–9	7.2	51	5.8
	5. 3.46	0–9	6.8	60	6.05
	15.11.46	0–9	6.2	58	6.05
	11. 2.52	0–9	5.3	55	5.25
	„	9–18	5.1	39	5.90
	10. 2.53	0–9	6.0	49	5.30
	„	9–18	5.2	56	5.60
Standard fertilizer plus lime	25.10.45	0–9	7.1	54	5.9
	5. 3.46	0–9	6.2	60	5.9
	15.11.46	0–9	6.8	62	6.1
	11. 2.52	0–9	6.1	78	6.5
	„	9–18	4.1	66	6.5
	10. 2.53	0–9	5.6	75	6.0
	„	9–18	4.3	68	6.3
Special fertilizer	25.10.45	0–9	6.7	54	5.8
	5. 3.46	0–9	6.7	61	5.95
	15.11.46	0–9	6.2	60	5.8
	11. 2.52	0–9	6.5	40	5.55
	„	9–18	2.9	79	6.05
	10. 2.53	0–9	5.5	48	5.50
	„	9–18	4.1	65	5.75
Special fertilizer plus lime	25.10.45	0–9	7.0	56	5.9
	5. 3.46	0–9	6.9	55	5.8
	15.11.46	0–9	6.8	59	6.0
	11. 2.52	0–9	4.8	94	6.25
	„	9–18	3.4	69	6.40
	10. 2.53	0–9	5.7	70	6.15
	„	9–18	4.2	70	6.10

made on 26 October 1945. In March 1946, samples of soil were obtained from between the rows of plants so as to avoid any contamination with fertilizer which would have been placed under the plants or would have been applied later as a side dressing. From each of the five replications of the treatments six cores, 2 inches in diameter, were used for a sample. In November 1947 two sets of samples were obtained, one a few days before application of the ground limestone and the other, marked L 11/47 in Fig. 1, a few days after the limestone was broadcast. Other applications were made in the springs of 1949 and 1951. It will be appreciated that in the first season of treatment, 1945–46, most of the ground limestone would be in the top few inches of soil so that differences in analytical data for subsoils of unlimed and limed areas would be small or non-existent. In the spring of the 1946–47 season the limestone would have become mixed through the soil to some extent by cultural operations. The data for samples of November 1946 show the effect of the dressings of ground limestone in increasing the exchangeable CaO content, but with as yet only a small effect on the pH value. Later sets of samples show an increasing effect on these determinations by succeeding applications of ground limestone. Samples taken following

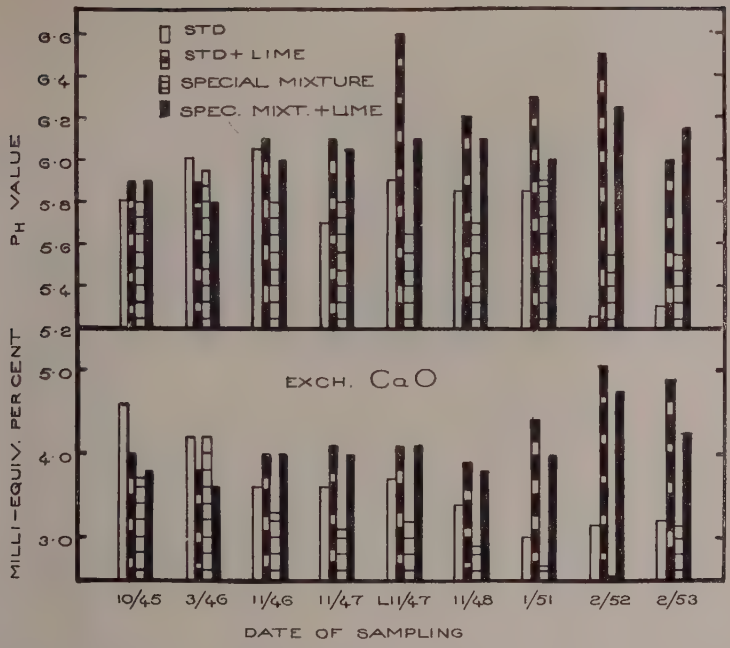

Fig. 1.—pH values and exchangeable CaO of soil samples.

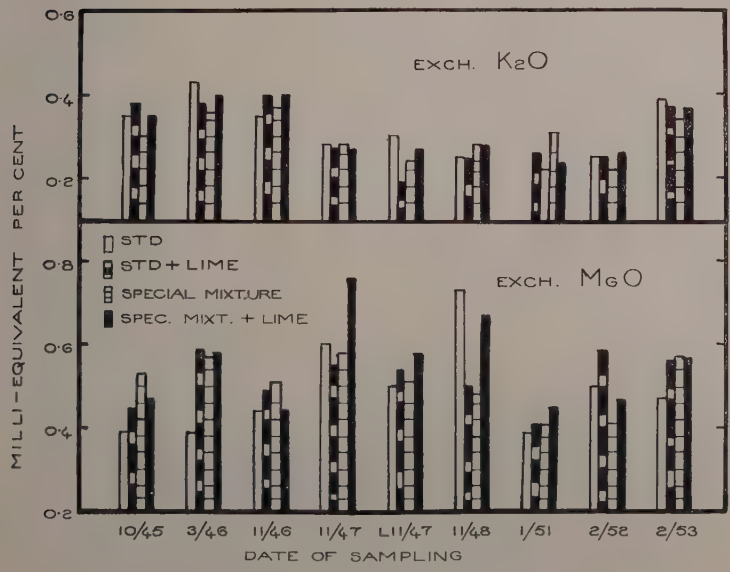

Fig. 2.—Exchangeable K_2O and M_gO of soil samples.

the biennial dressings show this especially in the pH values. During the course of the experiment there has been a distinct decrease in exchangeable CaO and pH value for those plots not receiving ground limestone. Use of the special fertilizer mixture has perhaps decreased the exchangeable CaO figure more than has use of the standard fertilizer, but on the other hand samples from plots receiving the latter show slightly lower pH values in the absence of ground limestone than those from areas receiving the special mixture.

Data for exchangeable potash (K_2O) and magnesia (MgO) are given in Fig. 2. Both of these constituents were present in relatively low amounts. Use of the two fertilizer mixtures, with or without ground limestone, has not consistently affected the amounts of exchangeable potash, but exchangeable magnesia has been increased at times by the applications of limestone.

Further analytical data are given in Table 3 where cation-exchange capacity (C.E.C.), percentage base saturation, and pH value are given for samples taken over 0–9 and 9–18 in. depths. These data show that the experimental area was reasonably uniform in base status when the experiment began in October 1945, the soil having a pH value of about 5.8, C.E.C. about 7 m.e.%, and a base saturation figure of a little over 50%. Taking in particular the data for the samples of 11 February 1952 and 10 February 1953, it is seen that the cation-exchange capacity has fallen by about the same amount over the course of the experiment whether ground limestone was used or not; on the unlimed areas the percentage base saturation has decreased slightly in parallel with the slight fall in pH value. On the other hand, where ground limestone was used the percentage base saturation has been increased in both the 0–9 in. and the 9–18 in. samples where the standard fertilizer was used. It may be noted that the percentage base saturation is positively correlated with the pH value of the soil.

Summarizing, therefore, where standard tobacco fertilizer was used over the period there has been very little change in the pH of the soil. The use of lime at the rate of ½ ton every second season, a total of 2 tons in 8 years, has resulted in a rise to pH 6.3. Where the special calcium-free fertilizer alone was used, the pH has dropped to 5.5, but liming in conjunction with this fertilizer has brought the pH up to 6. These figures show a very close correlation between the pH of the soil and the use of calcium.

The analytical data obtained on these samples of soil show that on a sandy soil such as that of the Tobacco Research Station care is required in the use of ground limestone, or other basic material, that might be used to reduce soil acidity, owing to the danger of raising the pH value of the soil to such a degree that the organism causing black root-rot may be encouraged to develop, or that the availability of minor elements such as boron may be decreased with resultant appearance of deficiency symptoms. The former state of affairs can be obviated by use of varieties resistant to root rot, but the latter is an ever-present danger should the use of ground limestone be too generous.

If it is assumed that the ground limestone was 95% pure, as was the first season's material, then over the eight years of this experiment 2,383 lb. CaO equivalent has been applied per acre. If moreover an acre of soil to a depth of 18 in. weighs 5 million pounds then this added

lime represents an increase of 477 p.p.m. CaO in the soil, or if all were exchangeable an increase of 1.70 m.e.%. Taking the analyses of the last set of samples it appears that the increases in exchangeable CaO for the standard fertilizer and the special mixture plots were 1.14 m.e. and 0.82 m.e. respectively over the 18 inches. Any differences in absorption of CaO by the crop due to the treatments are too small to affect these figures. The contribution of CaO from the superphosphate in the standard fertilizer must also be taken into account; over the eight seasons this would be equivalent to about 1 m.e.%. On this basis the CaO unaccounted for becomes 1.56 m.e. for the standard fertilizer and 0.88 m.e. for the special mixture. It is possible that some of the limestone particles have not been decomposed and thus would not contribute to the exchangeable CaO; but no determinations of free carbonate have been made on these soils. If leaching occurred at the rate of 500 lb. $CaCO_3$ equivalent per acre per annum the loss would be equivalent to 1.6 m.e.%. This is not excessive for a sandy soil such as that of the Station; moreover it would have been aided by the unusually wet springs of the 1951–52 and 1952–53 seasons.

LEAF ANALYSES

From cured leaf representative of the whole crop, samples were taken for chemical analysis during each of the eight seasons of the experiment. Soluble ash, insoluble ash, lime, magnesia, potash, phosphoric acid, nitrogen, and sugars contents were determined. The analytical data are expressed as percentages on the dry matter basis. Minimum, maximum, and mean values with the probable errors of certain of the latter are set out in Table 4; it has not been considered necessary to present all the data. The minimum, maximum, and mean values of the soluble ash and lime contents are greater in the samples from the limed than those from unlimed areas. Use of ground limestone under the conditions of this experiment has on the average increased the soluble ash content by 1.0% and the lime content by nearly 0.65% in each of the two sets of data; these differences are very significant. The effect on the lime content of the leaf is shown for the last five seasons of the experiment in Fig. 3. Insoluble ash, magnesia, potash, and phosphoric acid contents have not been significantly altered by liming. It is interesting to note in the individual data that the magnesia content decreased throughout the experiment, so that the minimum figures recorded in Table 4 were found at the end of the experiment. Although the mean values for total nitrogen were the same for unlimed and limed samples from each pair of fertilizer comparisons, it is clear from Fig. 3. that seasonal effects were greater on the limed areas. Total reducing sugars were not significantly altered over the eight seasons by the use of ground limestone with both fertilizer mixtures. Seasonal variations were considerable however (Fig. 4); as with nitrogen there was a greater range in values for the limed than for the unlimed material from season to season, with the result that the reducing sugars contents of samples from the limed areas might at one time be greater, and at another time be less, than the corresponding unlimed ones. Glucose was determined separately in four seasons; it was significantly increased by liming in conjunction with the standard fertilizer, but for the special mixture a slight decrease was found on liming. Sucrose content was not significantly affected by liming. The range of values shows however that seasonal effects were appreciable. It is very noticeable that variations in the nitrogen and

reducing sugars contents are not nearly so marked in later as in the earlier years of the experiment.

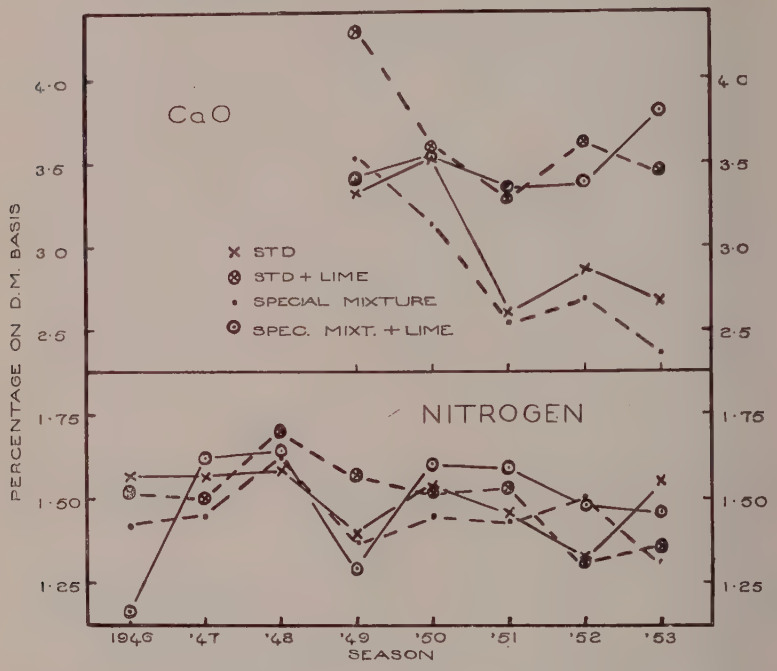

Fig. 3.—Nitrogen and CaO contents of tobacco leaf laminae.

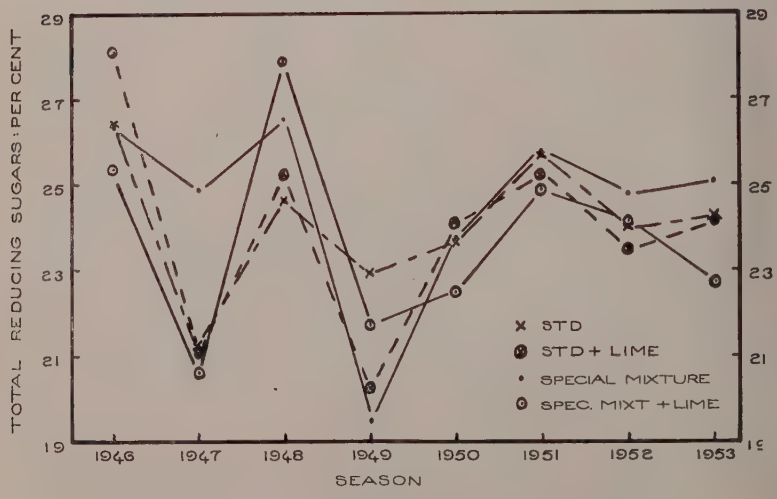

Fig. 4.—Total reducing sugars contents of tobacco leaf laminae.

TABLE 4. CHEMICAL COMPOSITION OF BLADES OF CURED TOBACCO LEAVES
Expressed as percentage on dry matter basis

Treatment	Level	Soluble Ash	Insoluble Ash	CaO	MgO	K_2O	P_2O_5	Total N	Total Reducing Sugars	Glucose	Sucrose
Standard fertilizer	Minimum	8.82	0.13	2.61	0.20	1.99	0.47	1.32	21.24	13.07	1.23
	Maximum	10.77	0.21	3.53	0.40	2.71	0.59	1.58	26.40	14.65	5.01
	Mean	9.87	0.17	3.01	0.31	2.25	0.51	1.50	24.10	13.98	3.08
	P.E. of mean	±0.26	—	±0.12	—	±0.08	±0.015	-	—	±0.22	—
	5% limits of mean								±0.37		
Standard fertilizer plus lime	Minimum	10.19	0.16	3.29	0.19	1.71	0.49	1.32	20.27	13.89	0.30
	Maximum	12.20	0.24	4.29	0.36	2.82	0.71	1.70	28.08	17.45	4.43
	Mean	10.87	0.20	3.65	0.27	2.17	0.55	1.50	23.96	15.37	2.63
	P.E. of mean	±0.25	—	±0.11	±0.024	±0.12	±0.03	—	—	±0.49	—
	5% limits of mean	±0.35		±0.16		±0.14				±0.54	
Special fertilizer	Minimum	7.98	0.12	2.37	0.20	1.88	0.43	1.31	19.52	14.01	2.04
	Maximum	10.65	0.18	3.53	0.43	2.79	0.54	1.63	26.57	17.23	5.49
	Mean	9.21	0.14	2.86	0.31	2.16	0.50	1.44	24.60	15.84	3.37
	P.E. of mean	±0.30	—	±0.14	—	—	±0.017	—	±0.53	±0.46	—
	5% limits of mean					±0.11					
Special fertilizer plus lime	Minimum	9.90	0.15	3.39	0.23	1.91	0.49	1.21	20.61	14.56	1.32
	Maximum	10.80	0.18	3.81	0.46	2.78	0.63	1.64	27.87	14.94	6.38
	Mean	10.25	0.17	3.50	0.32	2.16	0.54	1.47	23.73	14.81	3.00
	P.E. of mean	±0.11	—	±0.06	—	—	±0.019	—	±0.55	±0.10	—
	5% limits of mean	±0.32		±0.15					±0.76	±0.47	

Mineral analysis cover 5 seasons (1949-53), and nitrogen, total reducing sugars and sucrose 8 seasons. (1946-53): Glucose for seasons 1946-48, and 1953 (4 seasons).

Discussion

The use of lime in what would be considered fairly liberal applications for a sandy soil has resulted in an increased yield of flue-cured tobacco. This has not been associated with any delay in ripening or reduction in leaf quality. These results are somewhat at variance with experience in other countries. It is suggested that the difference may lie in the presence of volunteer legumes in overseas tobacco lands and their relative absence on the soil on which the experiment was carried out. Lime would stimulate the growth of such legumes which in turn would build up the organic nitrogen to undesirable levels and hence cause a delay in maturity and a lowering of quality. In the eight years of the experiment no deficiency symptoms showed up, although in an adjacent area a very heavy application of lime brought on boron deficiency. The use of lime however has raised the pH considerably; from 5.6 to 6.0 is considered optimum for flue-cured tobacco, and the upper limits of this range were reached and even exceeded in the limed plots. The trial was carried out on clean soil where black root-rot is not a factor. Where this disease is present, the soil pH becomes of primary importance. Below pH 5.6 the fungus does little harm, but as the pH rises the disease becomes more active and takes a greater toll of the crop. As the fungus is present in a wide range of N.Z. tobacco soils it is important that this aspect be closely considered. As a result of the trial it is concluded that lime can be used on N.Z. flue-cured-tobacco soils with beneficial results provided a close watch is kept on the pH.

Acknowledgements

Thanks are due to Mr. W. B. Taylor of the Applied Mathematics Laboratory of the Department of Scientific and Industrial Research, for the statistical analysis in Table 1. The authors also wish to thank Miss K. E. Currie and Mr. G. Ward for assistance with the analytical work.

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GLASSHOUSE TESTS FOR CONTROL OF ANTIRRHINUM RUST

By H. Jacks* and A. J. Webb, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(Received for publication, 25 May 1956)

Summary

The most effective compounds for control of Antirrhinum rust (*Puccinia antirrhini* Diet. and Holw.) under glass were zineb, wettable sulphur, ferbam, maneb, dichlone, thiram, colloidal sulphur, and lime sulphur plus colloidal sulphur.

Introduction

Antirrhinum rust (*Puccinia antirrhini* Diet. and Holw.) was first reported in New Zealand by Helson (1953). Those fungicides promising for control of French-bean rust (Jacks and Brien, 1955) were used in tests here described to ascertain their effectiveness in control of Antirrhinum rust.

Materials and Methods

Lime sulphur	(15% polysulphides) liquid;
Colsul 40	(40% colloidal sulphur) paste;
Red Star	(40% colloidal sulphur) paste;
Cosan	(75% sulphur) wettable powder;
Aasulpha Supra	(75% sulphur) wettable powder;
Dithane Z 78	(65% zineb) wettable powder;
Dithane D-14	(x/y/z = x lb. of 19% nabam /y lb. of zinc sulphate /z lb. of hydrated lime) tank mix formulation;
Fermspray	(70% ferbam) wettable powder;
Fertram	(80% ferbam) wettable powder;
Manzate	(70% maneb) wettable powder;
Dithane M 22	(70% maneb) wettable powder;
Thirospray	(50% thiram) wettable powder;
Tetram	(80% thiram) wettable powder;
Fuclasin Ultra	(80% ziram) wettable powder;
Zirospray	(70% ziram) wettable powder;
Phygon XL	(50% dichlone) wettable powder;
Spergon w.p.	(48% chloranil) wettable powder;
Nirit	(15% sulfocyano dinitrobenzene) wettable powder;
Orthocide	(50% captan) wettable powder.

Antirrhinum plants, variety Majestic (semi dwarf), were sprayed with the fungicidal suspensions when 9 in. high; one hundred ml. were used for each set of 5 plants per treatment. Twenty-four hours later, plants were inoculated by spraying with a suspension containing 30,000 rust spores per ml. and placed in a humidity cabinet (97% relative humidity at 65°F.) for 24 hours. Plants were then held in a glasshouse at 68.5 ± 4.5°F.

* Now at Massey Agricultural College, Palmerston North.

Lesion counts summarized in Table 1 were made on 4 leaves per plant 17 days after inoculation.

TABLE 1 RESULTS FROM GLASSHOUSE TESTS FOR CONTROL OF ANTIRRHINUM RUST

Means from 2 replications each of 5 plants

Treatment	Amounts in lb. per 100 gal. water	Lesions per leaf	
		Mean No.	Log (X + 1)
Cosan	5.3	0.0	0.00
Dithane Z 78	2	0.0	0.00
Dithane D 14	1 + 0.5 + 0.25	0.0	0.00
Dithane M 22	0.5	0.1	0.03
Fermspray	1	0.1	0.03
Phygon XL	0.5	0.2	0.05
Manzate	0.5	0.5	0.12
Thirospray	4	0.5	0.08
Aasulpha Supra	5.3	0.6	0.16
Colsul 40	10	0.7	0.13
Tetram	2.5	0.7	0.20
Fertram	0.87	1.7	0.32
Lime sulphur + Red Star	6.2 + 2	1.8	0.26
Red Star	10	2.8	0.42
Orthocide	4	4.6	0.71
Spergon w.p.	0.5	5.7	0.80
Zirospray	4	6.0	0.82
Nirit	6.7	7.4	0.89
Fuclasin Ultra	3.5	17.6	1.24
Check—water	—	516.3	2.69
Sig. Diff. at 1%:			0.43

RESULTS

All treatments, as compared with checks, caused a highly significant reduction in the number of rust lesions produced while there were differences in efficiency between materials.

In the table, materials are listed in order of effectiveness and may be grouped as follows:

(a) Those allowing production of 0–3 lesions viz. not significantly different from 0: Cosan, Dithane Z 78, Dithane D 14, Dithane M 22, Fermspray, Phygon XL, Manzate, Thirospray, Aasulpha Supra, Colsul 40, Tetram, Fertram, Lime Sulphur + Red Star, and Red Star.

(b) Those allowing 3–6 lesions: Orthocide and Spergon w.p.

(c) Those allowing 6 or more lesions, or not significantly better than the least effective: Zirospray, Nirit, and Fuclasin Ultra.

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SEED DISINFECTION

XIV. EFFECT OF SEED DRESSINGS ON DAMPING-OFF AND NODULATION OF LUCERNE

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(Received for publication, 2 July 1956)

Summary

It was shown that *Pythium ultimum* Trow. caused damping-off of lucerne seed.

Seed dressings based on dichlone, captan, thiram, and ferbam effectively increased emergence under conditions of the experiments.

Treatments did not completely prevent post-emergence damping-off, but dichlone, captan, and to a lesser extent thiram gave significant reduction of diseased seedlings.

Development of *Rhizobium meliloti* Dangeard was not affected by materials under test, when seed was sown immediately after dressing.

Introduction

Damping-off patches were observed in lucerne fields and the causal organisms were identified as *Pythium ultimum* Trow. by Dr. H. C. Smith (pers. comm.). The degree of protection from damping-off afforded by various seed dressings was investigated to ascertain if it was possible to re-establish the crop on the almost bare areas by oversowing. As seed inoculation with *Rhizobium* is general practice in lucerne-growing in New Zealand, effects of seed dressings on nodule development when treatment was carried out almost simultaneously with inoculation was also measured.

Materials and Methods

Certified lucerne (*Medicago sativa* L.) seed used had a germination capacity of 82% on filter paper (room temperature).

Materials listed below were tested as percentages of seed weight and applied in a rotary shaker. Organic mercury compounds: Agrosan (1% as phenyl mercury acetate), Betanal (2.8% Hg as methoxy ethyl mercury silicate), Ceresan (1.5% Hg as phenyl mercury acetate and ethyl mercury chloride), Kleenseed (1.2% Hg as ethyl mercury chloride), and Leytosan (1% Hg as phenyl mercury chloride).
Chloranil: Spergon (98%) and Tetroc (98%).
Dichlone: Phygon XL (50%).
Captan: Orthocide 75 (75%).
Nitrobenzene: Tritisan (20%), Folosan (16%), Nirit (45%).
Thiram: Fernasan (50%), Premasan (50%) and Thirodust (75%).
Copper oxychloride: Cuprox (50%), and Cop-ox (50%).
Cuprous oxide: Perenox (50%) and Cupromox (50%).
Ziram: Fuclasin Ultra (70%) and Zirospray (70%).
Zineb: Dithane Z 78 (65%).
Ferbam: Fermspray (70%) and Fertram (80%).
Wettable sulphur: Aasulpha Supra (75%), and Cosan (75%).

* Now at Massey Agricultural College, Palmerston North.

A light volcanic potting loam, steam disinfected for 15 min. at 200 ± 10°F. was used in these tests. *P. ultimum* cultures grown on sand + oatmeal were mixed with soil, and three weeks were allowed for distribution of mycelial growth. Soil for tests was inoculated, at 5% of its volume, with the above preparation, thorough distribution being assured by hand mixing and sieving. Soil moisture was maintained at 35% water-holding capacity.

Five replications each of 80 seeds were used for each treatment. Glasshouse temperatures throughout the tests were 68 ± 7°F. Three weeks after sowing, records were made of total emergence and of seedlings showing symptoms of post-emergence damping-off. The latter included plants showing minor lesions as well as those that were dead. Percentages of emergence were calculated on number of seeds sown and percentages of diseased seedlings on numbers emerged.

The following tests were made:

1. Phytotoxicity of materials applied at 2% of seed weight was investigated in steam disinfected soil.
2. Effect of three dosage levels was determined in *Pythium*-inoculated soil.
3. Selection of materials at the lowest effective dosage was carried out in *Pythium*-inoculated soil. *Rhizobium* compatibility was tested by inoculating seed with cultures of *Rhizobium meliloti* Dangeard by the standard skim-milk method either immediately before or immediately after application of seed dressings. Seed was sown immediately after treatment and the number of nodule clusters was recorded three weeks later.

RESULTS

Phytotoxicity tests. No material significantly increased or decreased emergence over checks.

Dosage tests. As facilities did not permit the use of all compounds, this and further tests were carried out with one material representing each chemical group viz. Agrosan, Spergon, Phygon XL, Orthocide 75, Tritisan, Thirodust, Cop-ox, Perenox, Fuclasin Ultra, Dithane Z 78, Fermspray and Cosan. Results are given in Table 1.

None of the treatments, at any concentration, significantly increased emergence. Cosan alone, at the highest concentrations, significantly depressed emergence.

Significant decrease of post-emergence infection, compared with checks, was brought about by Orthocide 75 and Thirodust at all concentrations, Fuclasin Ultra, Dithane Z 78, and Fermspray at two concentrations, and Tritisan, Cop-ox, and Perenox at one concentration.

Selection tests and Rhizobium compatibility. As the interaction between treatments and dosages (Table 1) was not significant, materials were applied at the lowest dosage used viz. 0.5% of seed weight. The compatibility of seed protectants with *Rhizobium* was also investigated during selection tests, viz. in test 1 seed was not inoculated, in 2 it was inoculated before application of materials and in test 3 materials were applied before inoculation. Results of nodule counts are not given

TABLE 1. Effect of Seed Dressings on Emergence of Lucerne in Soil Inoculated with *P. ultimum*

Trettment	Emergence Per cent			Diseased seedlings Per cent			Equivalent angle		
	*0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0
Check	41.8	41.8	41.8	33.9	33.9	33.9	34.2	34.2	34.2
Agrosan G.N.	43.2	40.3	31.7	20.3	18.8	19.8	26.2	25.0	26.0
Spergon	33.2	36.7	37.0	20.5	15.3	15.5	26.8	23.0	22.8
Phygon XL	40.7	37.3	33.1	14.6	16.8	13.0	21.8	23.4	20.2
Orthocide 75	52.5	42.9	50.0	10.5	5.9	6.6	17.8	13.8	14.4
Tritisan	47.0	46.3	39.1	12.9	23.8	16.7	20.4	28.6	24.0
Thirodust	46.2	48.0	52.7	9.8	12.8	6.0	17.4	20.8	13.6
Cop-ox	42.7	43.8	45.0	20.4	14.6	12.8	26.6	22.4	20.8
Perenox	35.8	42.8	35.6	7.0	15.0	22.0	15.4	21.6	27.4
Fuclasin Ultra	49.2	44.2	45.2	18.7	8.9	8.3	23.8	15.2	16.0
Dithane Z 78	38.8	45.3	48.0	15.9	9.2	9.5	22.6	15.4	15.0
Fermspray	47.1	47.6	42.3	1.9	7.2	25.0	6.2	14.6	29.2
Cosan	39.2	38.6	27.6	20.7	35.3	43.8	25.8	36.4	41.2
Sig. Diff. at 1%		11.4			—			12.7	

* Dosages as percentages of seed weight.

in Table 2 as differences between treatments in all tests and the reaction between tests over all treatments were not significant. Nodule development in checks showed that the soil had been re-infected with *Rhizobium*.

Phygon XL, Orthocide 75, Thirodust, and Fermspray consistently increased emergence whilst Tritisan and Fuclasin Ultra were less effective. Agrosan, Spergon, Cop-ox, Dithane Z 78, and Perenox did not increase emergence in any test. Phygon XL and Orthocide 75 consistently reduced post-emergence infection. Thirodust was effective in two out of three tests and Fuclasin Ultra in one test. None of the other materials significantly reduced infection.

Conclusion

None of the compounds tested, with the exception of sulphur (Cosan), decreased emergence.

An increase in emergence was brought about by dichlone (Phygon XL), captan (Othocide 75), thiram (Thirodust), and ferbam (Fermspray), and to a lesser extent by nitrobenzene (Tritisan).

Post-emergence infection was significantly reduced by dichlone (Phygon XL) and captan (Orthocide 75), and to a lesser extent by thiram (Thirodust).

TABLE 2. EFFECT OF SEED DRESSINGS (0.5% of seed weight) ON EMERGENCE OF LUCERNE IN SOIL INOCULATED WITH *P. ultimum*

Treatment	Emergence Per cent			Diseased seedlings					
				Per cent			Equivalent angle		
	Test			Test			Test		
	1	2	3	1	2	3	1	2	3
Check	50.8	54.0	49.6	47.5	45.1	62.1	43.8	42.2	52.4
Agrosan	63.4	52.8	60.0	27.1	52.0	46.4	29.6	43.1	46.1
Spergon	62.8	62.0	54.3	36.1	43.7	65.9	35.8	41.3	54.7
Phygon XL	75.2	71.2	75.6	18.6	16.0	19.0	21.0	21.4	22.6
Orthocide 75	78.0	74.4	74.0	19.7	14.3	14.5	24.6	21.6	22.0
Tritisan	66.0	65.6	63.6	36.9	45.2	41.4	36.8	42.0	39.0
Thirodust	65.2	73.2	67.0	42.7	22.5	18.7	40.6	26.8	23.8
Cop-ox	58.8	62.8	60.8	50.6	32.2	40.3	45.2	35.8	42.2
Fuclasin Ultra	66.4	58.4	62.4	59.2	52.6	30.8	50.4	46.4	32.8
Dithane Z 78	62.0	62.0	48.8	61.1	50.5	44.2	51.6	45.2	41.6
Fermspray	64.4	70.8	73.2	59.4	23.6	45.7	50.4	28.2	42.4
Pernox	51.6	54.6	51.2	58.8	53.0	68.6	50.0	47.0	55.6
Sig. Diff. at 1%:	13.5	9.6	16.8				17.1	14.7	19.2

Nodule cluster counts indicated that nodulation took place irrespective of treatment. No differences were measured between the rate of nodulation on plants from uninoculated seed or those from seed inoculated immediately before or after seed dressing application.

It can therefore be concluded that, where damping-off patches occur in lucerne fields, dusting seed with dichlone, captan, or thiram would facilitate re-establishment over these areas.

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STUDIES ON METABOLIC DISORDERS IN DAIRY COWS

II. OBSERVATIONS ON THE AETIOLOGY OF METABOLIC DISORDERS IN FOUR WAIKATO DAIRY HERDS

By J. B. Swan and N. D. Jamieson, Animal Research Station, Department of Agriculture, Wallaceville

(Received for publication, 10 February 1956)

Summary

Concurrently with the field survey of metabolic disorders in dairy herds (Swan and Jamieson 1956) a fairly detailed investigation was made of four typical neighbouring dairy herds in the Waikato district. Two of these herds had a record of little or no incidence, and two a record of regular and fairly marked incidence of metabolic disorders. The biochemical data on normal cows and on clinical cases of metabolic disease in these herds are presented in this paper together with a brief account of some of the major differences in feeding methods practised in these four herds. In addition, a general account is given of the feeding and managemental conditions in a number of other herds where metabolic disorders occurred.

Observations on Four Waikato Herds

The observations on the four Waikato herds chosen for detailed study cover the three years 1945–47. From six to twelve early spring-calving cows, comprising a representative sample of each herd, were bled and a sample of urine taken from two to six weeks both before and after calving as a normal routine, in order to detect any changes occurring following parturition in these herds. Whenever possible, additional samples were taken before treatment and after recovery from any of the sample cows or other cows in these herds which became clinically affected by any metabolic disorder.

The chemical results of the normal herd samples are summarised in Table 1. The records of cows which were showing any clinical abnormality at the time of sampling are not included in these averages, but are shown in detail in Table 2.

Herds A and B, hereafter designated "good" herds, were the two in which the incidence of metabolic disease had been nil or very low over the previous five or six years. Herds C and D, the "bad" herds, were those which regularly experienced from five to ten per cent incidence and from two to four per cent mortality from metabolic diseases.

The figures in Table 1 indicate that in all four herds there is a post-partum fall in the level of serum calcium, the lowest post-partum levels occurring in the bad herds. There is likewise a tendency for serum magnesium to fall post-partum in most years, the greatest falls and the lowest levels being found in the bad herds. The one notable exception to this finding was in Herd C in 1946 and 1947. It may be significant that the owner of Herd C installed bail-feeders in 1946, and fed a few pounds of crushed grain to the calved cows at milking times during August and September in 1946 and 1947. In 1945, before this extra feed was provided, this herd had the lowest average serum magnesium post-partum of the four herds.

TABLE 1. BIOCHEMICAL RESULTS FROM FOUR WAIKATO HERDS 1945–1947

Herd	Date	Time calved	No. cows	Serum		Blood			Urine Roth. Test
				Ca (mg%)	Mg (mg%)	T.a.b. (mg%)	Gluc. (mg%)	Inorg. P. (mg%)	
"Good" Herd A.	23.6.45	a-p.*	12	11.0	2.4		47	4.6	-ve
	13.8.45 and 27.8.45	13 d.	8	10.1	2.4	6.6	48	4.6	2+
	19.6.46	a-p.	12	10.5	2.7	—	44	—	-ve
	9.9.46	5 wk.	12	10.4	2.1	5.0	39	—	1+
	8.7.47	a-p.	6	10.6	2.3	—	45	5.1	-ve
	26.8.47	12.5 d.	6	10.2	2.5	—	46	5.1	-ve
"Good" Herd B.	24.6.45	a-p.	6	10.8	2.2	—	52	4.3	-ve
	10.8.45	3 wk.	5	10.4	1.9	6.8	56	4.3	1+
	18.6.46	a-p.	10	11.1	2.6		44		-ve
	7.9.46	5 wk.	9	10.9	1.9	4.7	38		1+
	9.7.47	a-p.	7	10.6	2.6		38	4.6	1+
	26.8.47 and 23.9.47	3.5 wk.	7	10.1	2.6		40	4.2	1+
"Bad" Herd C.	20.6.45	a-p.	11	10.5	2.0	3.6	48	4.0	-ve
	14.8.45 and 6.9.45	3 wk.	11	10.0	1.5	7.5	83	4.3	1+
	17.6.46	a-p.	11	11.1	2.0				-ve
	6.9.46 and 25.9.46	3 wk.	8	9.9	2.2	3.5	42		-ve
	8.7.47	a-p.	7	9.9	2.5		37	5.1	-ve
	27.8.47	3 wk.	7	9.6	2.3		40	4.2	-ve
"Bad" Herd D.	21.6.45	a-p.	10	10.0	2.1	1.6	46	4.0	-ve
	9.8.45 and 15.9.45	3 wk.	10	9.9	1.6	7.9	55	3.5	2+
	18.6.46	a-p.	12	10.6	2.6				-ve
	5.9.46 and 19.9.46	3 wk.	9	9.9	2.0	2.3	42		-ve
	8.7.47	a-p.	6	10.3	2.3		44	4.8	-ve
	27.8.47 and 23.9.47	24 d.	6	9.7	1.8		37	3.6	5+

* a-p. ante-partum

TABLE 2. Metabolic Disorders Occurring in Four Waikato Herds 1945–1947

Herd & Cow No.	Date Bled	Date Calved	Age (Yr.)	Serum		Blood			Urine		Case Notes
				Ca	Mg	T.a.b.	Gluc.	Inorg. P.	Roth. Test	T.a.b.	
A 1	25.8.46	24.8.46	9	4.4	3.0	1.1	60		±	14	Mild milk fever Treated and recovered. A very high-producing cow.
B 1	7.9.46	14.8.46	4	10.9	0.8	22.0	25		1+		Routine post-partum sample. Cow thin and scouring.
	19.9.46			6.8	2.9	22.0	63		3+	186	Nervous and staggery. Bled 7 hrs. after dosing chloral.
B 2	3.6.46			Not in group under observation							Milk fever (?). Treated 4 times and recovered.
B 3	28.7.46	about 3 weeks calved	3			,, ,, ,, ,, ,,					Mild grass staggers. (?) Treated by dosing chloral, $MgSO_4$, and molasses. Recovered in about a week.
B 4	5.9.46										
B 5-6	20.8.47	about 3 weeks calved	4			,, ,, ,, ,, ,,					Same two cows affected as last year. Mild grass staggers (?). Treated and responded similarly.
C 1	13.9.45	10.9.45	7	5.2	1.9	8.9		1.7	30+		12/9 Staggery. Dosed molasses and $MgSO_4$. 13/9 Recumbent.
	14.9.45			12.8	3.5	6.2	77	5.4	+?		Injected calcium and dextrose. 14/9 Still down. Eventually destroyed.
C 2	20.6.45			10.2	1.9	3.8	38	3.3	-ve		Routine ante-partum sample.
	14.8.45	21.7.45	9	8.6	0.7	10.4	44	4.8	1+	16	Routine post-partum sample. Clinically normal.
	21.8.45			12.7	0.9	7.9	119	7.3	+?		Peracute tetany. Sample taken 30 min. post-mortem. A high-producing cow.
C 3-7	1945			No samples taken							Five other milk fevers of which two died.
C 8	17.6.46			10.7	1.5		46		-ve		Routine ante-partum sample.
	24.8.46	21.8.46	5	5.7	1.1	1.9	50		+?	18	Staggery. Retained placenta, poor condition. Injected calcium and dosed stilboestrol.

	6.8.46			9.8	1.9	2.2	51		-ve	Recovered. A high-producing cow. Culled 1947 because of mastitis.
C 9	13.9.46	11.9.46	7	7.7	3.2	3.0	54			Went down once. Standing when treated by calcium injection. Recovered.
C 10	4.9.46	23.8.46	8	10.5		1.4	55		-ve	Went down 1 day post-partum. No response to calcium injection. Destroyed 4.9.46. Had stillborn calf.
C 11	15.9.46	13.9.46	6	5.7	3.1	4.0	54			Went down twice. Standing when treated by calcium injection. Recovered but went dry.
C 12	10.9.46	9.9.46	9	6.6		31.5	121			Dull and staggery. Treated by calcium injection. Poor condition, anorexia, listless, but milking fairly well. Culled later for tuberculosis.
	25.9.46			6.3	1.4	2.5	50		-ve	
C 13-15	1946			No samples taken						Three other milk fever (?) cases, of which two died, one from aspiration pneumonia.
C 16	27.8.47	31.7.47	3	9.9	1.6		36	3.3	-ve	Recovered grass staggers. Still occasionally nervous. Treated by molasses and $MgSO_4$ dosing.
C 17	27.8.47	27.7.47	3	11.3	2.3				-ve	Recovered grass staggers. Treated as C 16. Normal now.
C 18	1947		6	No samples taken						Milk fever (?). Not treated early. Destroyed after being down one week.
C 19	1947			No samples taken						Aborted in April. Intermittent tetanic seizures during winter. Drenched several times. Died after a tetanic seizure.
D 1	25.7.45	14.7.45		9.0	1.2	25				Had grass staggers (?) in 1944. 24.7.45, mouthing hay and posts; dosed molasses 6 p.m. 25.7.45, went down; calcium and dextrose injected. 26.7.45, still down; treated again. 29.7.45, still down; treated again; recovered. 9.8.45, routine post-partum sample.
	26.7.45			5.1	0.6	11				
	29.7.45			5.8	0.6	10				
	9.8.45			10.2	1.9		53	4.3	2+	

(Table 2 continued)

Herd & Cow No.	Date Bled	Date Calved	Age (Yr.)	Serum		Blood			Urine		Case Notes
				Ca	Mg	T.a.b.	Gluc.	Inorg. P.	Roth. Test	T.a.b.	
D 2	21.6.45			10.1	2.1	1.9	44	3.8			Routine ante-partum sample.
	28.7.45	19.7.45		3.7	0.4	24					Recumbent and dull. Dextrose injection provoked tetanic convulsions. Calcium injected increased force and rate of heart. Died soon after injection. Magnesium injection not given.
D 3	21.6.45			10.8	1.8	1.6	48	3.5			Routine ante-partum sample. Had grass staggers (?) 1944. Nervous and staggering. Calcium and dextrose injected. Chloral and molasses dosing prescribed. Recovered.
	6.8.45	1.8.45	9	5.5	0.7	4.0					
	9.8.45			9.5	1.2		52	2.3	1+		Routine post-partum sample.
	23.8.45			8.2	0.7	31	35	1.5	20+	110	*Milk:* Rothera 1+, T.A.B. 10mg%. Trembling and nervous. Molasses dosed.
	15.9.45			10.2	0.9	16	53	2.9	30+		Still nervous when bled.
D 4	23.8.45			6.1	0.8	1.7			-ve		Dull and not feeding. In early stage of gangrenous mastitis.
D 5-6	1945			No samples taken							Two other milk fever (?) cases. Responded to calcium and dextrose injection.
D 7	1946			No samples taken							Milk fever with bloat (numbered D. 1 in 1945). Died before treatment.
D 8	1.9.47	4.8.47	5	6.4	1.0	2.8	167	3.4			Several mild tetanic seizures since calving culminating in a major attack in the bail on 1.9.47. Calcium and magnesium injected. Recovered. Had lost condition since calving.
D 9-11	1947			No samples taken							Two milk fevers died, one during the night, one after treatment. Also one grass staggers (?) died during the night.

Total acetone bodies in the blood showed a tendency to be higher post-partum in the bad herds in 1945, but not in 1946. The Rothera test for urine acetone bodies in all four herds tended to give stronger reactions post-partum, the strongest reactions occurring in Herd D.

Blood-sugar levels were fairly stable and showed no consistent changes post-partum. A few average values above 50 mg% deserve comment, however. The average of 52 mg% in Herd B antepartum in 1945 was probably due in part to excitement in these cows when being sampled. The other values above 50 mg% were obtained in Herds B, C, and D post-partum in 1945. The same factor of nervous excitement may have contributed to these higher values, but it is significant that these cows on the same dates had low average serum magnesium values. It has been shown by Swan and Jamieson (1956) and also by Allcroft (1947), that hyperglycaemia is frequently associated with hypomagnesaemia in cows clinically affected by metabolic disorders. Two cows in Herd C on 14 August 1945 (post-partum) had blood sugar levels of 270 and 145 mg% in association with serum magnesium levels of 1.1 and 0.6 mg%. Both cows were apparently clinically normal at the time. Both were bled again on 6 September when the blood sugar values were found to be 67 and 61 mg%, and the magnesium 2.4 and 2.3 mg%.

No significant changes in herd averages for inorganic phosphate were observed, although the greatest and most consistent post-partum fall occurred in Herd D.

The chemical data on the clinical cases sampled in the four herds are given in full in Table 2, with a brief summary of the salient clinical observations made.

Cases marked as doubtful were those that were not sampled for chemical confirmation of the diagnosis, which was in some cases based

TABLE 3. SUMMARY OF THE METABOLIC DISEASES IN FOUR WAIKATO DAIRY HERDS IN 1945–1947

	Herd A (65 cows)	Herd B (55 cows)	Herd C (120 cows)	Herd D (62 cows)
1945	No metabolic diseases	No metabolic diseases	6 milk fevers (one confirmed as low Ca) 2 deaths. One acute grass staggers (low Ca-Mg) died	2 milk fevers (?) 2 grass staggers plus ketosis (low Ca-Mg, ketosis), one death. 1 grass staggers (low Ca-Mg)
1946	1 milk fever (low Ca)	1 milk fever 2 mild grass staggers (?) 1 grass staggers plus ketosis (low Ca-Mg, ketosis)	6 milk fevers (2 low Ca), 3 deaths, 2 mild grass staggers (low Ca-Mg)	1 milk fever (?) with bloat, died before treatment. Had had grass staggers-ketosis two previous years
1947	No metabolic diseases	2 mild grass staggers (?) (same two cows as last year)	1 milk fever (?) died. 3 mild, chronic grass staggers (?) 1 eventually died	2 milk fevers (?) both died. 1 grass staggers (?) died. 1 mild grass staggers (low Ca-Mg), recovered

on the owner's description and in others on that of the veterinarian attending the case. The total cases of metabolic diseases are summarised briefly in Table 3.

The types of clinical cases occurring in the four herds, especially in the bad herds, are a good reflection of the biochemical picture in the representative sample cows in the herds. Herd C had the highest incidence of milk fever, while the normal cows in this herd were lower in serum calcium before and after calving than those in the good herds. The incidence of grass staggers of the low calcium—low magnesium type is also reflected in the herd averages. Herd D had cases of milk fever, grass staggers, and grass staggers plus ketosis, which correlates well with the average herd blood picture.

There were marked differences in feeding practices between all four herds, especially between the good and bad pairs of herds. The good herds were fed ample fair-quality hay both before calving during the winter, and after calving well into the spring, while the bad herds received about half as much hay per cow during the winter, and feeding ceased earlier in the spring. The good herds also received daily rationed amounts of autumn-saved pasture during their first 6-8 weeks of lactation, while the bad herds received little or none, their pasture during the early lactation period being predominantly or entirely pasture in a short, fresh, rapidly growing condition. As mentioned previously, Herd C was fed a little crushed grain at milking times in the early spring of 1946 and 1947.

The feeding on the four farms is well shown in the figures (Table 4) for the three-year average quantities of hay and silage and autumn-saved pasture provided as supplementary feed for the cows during winter and early spring. Silage and autumn-saved pasture have been expressed in terms of hay equivalents for the purpose of comparison of the total fodder conserved in the four herds. These conversions are based on data from several standard textbooks, and of necessity involve some rough approximations. The yields of autumn-saved pasture were estimated after field inspection.

TABLE 4. SUPPLEMENTARY FEED IN WINTER AND EARLY SPRING
(3-year average)

Herd	Hay & Silage (Hay equivs. cwt/cow)	Autumn-saved Pasture		Total Conserved Fodder (cwt. hay-equiv./cow)
		(acres/cow)	(cwt. hay equiv./cow)	
A	7	0.65	10	17
B	7	0.50*	6	13
C	4	0.25	4	8
D	8	Nil	0	8

* Shut rather late

It will be seen from the figures in the first two columns of Table 4 that herds A and B, the good herds, were well supplied with hay and autumn-saved pasture as compared with the bad herds, C and D. With

due allowance for the approximations involved in the conversion of silage and autumn-saved pasture into hay equivalent, the differences in feeding conditions are even more strikingly shown by the figures for total conserved fodder in the last column of Table 4.

INVESTIGATIONS IN OTHER HERDS

In the course of visits to metabolic-disease cases throughout the Waikato district in the spring seasons of 1945–47, information was obtained when possible as to the feed, management, and other environmental conditions in the herds prior to the occurrence of the clinical cases. Also several farms were visited on the recommendation of Waikato veterinarians, as having recently experienced a marked incidence of metabolic disease.

Outbreaks of metabolic disease were rarely heard of, cases in any one herd usually occurring sporadically throughout the season. Milk fever, where its incidence was heavy, was naturally spread out, depending on the spread of calving dates. On a few farms, however, a number of cases of grass staggers did occur within a period of one or a few days.

Investigation of about forty farms showed that several environmental factors, including feed and management conditions, were common to herds experiencing all types of metabolic disease. Some factors were found more commonly in association with milk fever, others more commonly with grass staggers. As no two farms or herds showed exactly the same set of conditions, it is best to deal with the individual factors themselves, rather than with farms.

It was noted that a few days of inclement weather, particularly a combination of rain, cold, and wind, often resulted in a marked increase in the number of calls received by veterinarians to metabolic-disease cases.

Those factors frequently found associated with all types of metabolic disorders were: strong lactational drive; a predominance of fresh, young pasture in the ration; and good bodily condition at calving. These three factors are complementary, and are among the prerequisites for high production in dairy cows. A strong lactational drive is to some extent an inherent physical quality in a cow, one of its components being a hormonal stimulus acting strongly during the early weeks of lactation, and waning gradually as lactation proceeds (Eckles and Palmer, 1916).

Other factors besides the above three are required for the achievement of high total or seasonal production. Among these are: freedom from disease, good feeding and management throughout lactation, and "persistency". Thus, it can be seen that cows may have a strong lactational drive and yet not be high producers if these other factors are lacking.

Many cows affected by metabolic diseases were high producers, but some were only moderate producers. In these, it was usually found that one or more of the prerequisites for high production, other than the first three mentioned above, were lacking; the commonest deficiency being good feeding throughout lactation. Most of the cases of metabolic disease occurring in the poorly fed herds were the higher-producing cows in those herds, or were or had been milking more heavily than their herd mates at the times of or prior to the attack. Some cases seen were

in rather small cows, whose seasonal yield was only moderate, but on a bodyweight basis would have compared favourably with that of high-producing large cows. Both high production and strong lactational drive were present in such cows, but were not obvious unless the efficiency of the cows was considered.

Feed quality and quantity were also found to be related to the incidence of metabolic disease. A predominance of pasture in the ration was in many cases found in affected herds, whether pasture supply was abundant or only moderate. If supplementary roughage was deficient, either through actual shortage or through poor quality, grass formed the main food source, and on farms where this too was in limited supply, it was usually young, fresh, and short in growth. In contrast to these conditions, metabolic disease incidence was low in herds receiving a good ration of fair quality roughage in addition to young pasture. Hay, roots, and mature autumn-saved pasture were a good protection against metabolic disease.

A high incidence of milk fever was associated with fatness at calving and a diet largely of pasture, and it occurred especially in mature cows, which had reached the peak of their lifetime production.

Grass staggers, alone or with ketosis, was found largely associated with fatness at calving, there usually being a loss in condition, sometimes very marked, prior to the symptoms appearing, coupled with very heavy milk and butterfat production and a diet predominantly of young, sappy, rich pasture. Cases occurred on farms well supplied with grass, but more frequently on those with mainly short grass. Grass staggers frequently affected cows at about the peak of the milk and butterfat production curve, at which time lactation stress would be greatest.

Cases were often seen or reported to occur at about the time of oestrus, and frequently in cows which were normally of a somewhat nervous, excitable temperament. Loss of condition before the occurrence of symptoms of grass staggers was not always noted, but some farmers reported that the affected cows appeared "tucked up", as though they had not been eating well, for a few days before the attack. Sudden changes of feed were often associated with an outbreak of grass staggers, such as that from a short-grazed paddock to a new paddock of fresh, lush growth. Such changes were often followed by diarrhoea and digestive disturbances resulting in loss of appetite and irregularity of milk yield. Sudden cessation of feeding-out hay was found to be associated with several outbreaks, including one herd in which six cows were affected on one day. Likewise, a sudden exhaustion of supplies of mature pasture resulting in complete dependence on young, new growth was followed by the occurrence of six cases in a week in another herd. Another striking example of the effect of a feeding change, in the same direction, was that of the introduction of five fat, high-producing, pedigree Jersey cows into an average grade herd. The other cows in this herd were only in fair to moderate condition, were about average producers, and were not troubled by metabolic diseases. Of the five introduced cows, three died of grass staggers, one of milk fever, and the fifth had milk fever but recovered. The feed conditions on this farm were quite well tolerated by fair-conditioned, fair-producing cows, but proved highly unsuitable for fat, high-producing cows. The latter were the five highest producers in the herd from which they were

purchased, and had been "primed up" for sale by their previous owner. Sudden descent from luxury to average commercial dairy-farm feed conditions applied too large a stress and they broke down when the added strain of lactation was applied.

So few cases of simple, uncomplicated ketosis were seen that little can be said about their aetiology. Those cases in which the environmental conditions were investigated were mostly very poorly fed, but had calved in good condition and were fairly good-producing cows. A number of these were individual house cows. Other cases were seen in which the ketosis was probably only secondary to some other condition causing anorexia, such as retained placenta, metritis, or lameness. These were only isolated cases in commercial herds, and could not be ascribed to feed conditions. A few other cases were seen in commercial dairy herds, but information as to their husbandry is lacking.

The two major aetiological factors in the metabolic diseases appear to be unsuitable feeding and forced lactation. The effect of these is to produce a negative balance in energy metabolism and possibly in mineral metabolism.

To sum up, it may be said that the feeding conditions most commonly associated with a high incidence of metabolic disease are: heavy feeding in late pregnancy and large intake of immature pasture in early lactation. Both these factors result in high initial and maximal milk and butterfat yields, the former due to fatness at calving (Woodward, Sheppard, and Graves 1933; Lees, McMeekan, and Wallace 1948), the latter due to the lactogenic factors in fresh, young herbage (Sjollema, 1930; Webster, 1936; Smythe, 1948; Kay, 1948). Thus methods of feeding may cause excessive lactational drain, which may be reinforced by the natural hormonal stimulus to lactation in recently calved cows (Eckles and Palmer, 1916) and by the inherent lactational drive of naturally high producing cows.

Not all of these factors need operate in every animal suffering from one of the metabolic diseases, but one or more may be found in all cases. Other influences add their effect to the above factors: oestrus, inclement weather, and digestive disturbances following abrupt changes in feed. The role of these is probably that of precipitating agents; the proverbial "last straw" that leads to metabolic break-down.

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BORON AND FLUE-CURED TOBACCO

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Summary

The addition of borax at the rate of 5 lb. per acre to flue-cured tobacco fertilizer resulted in some increase in yield and a marked increase in leaf quality; 10 lb. per acre caused some delay in early growth and subsequent maturity of the crop. There appeared to be a correlation between the effect of boron on the crop and the rainfall at planting time.

Use of borax exerted little or no effect on the reducing sugars and nitrogen contents of the leaves. The boron content of the leaves was increased proportionally to the amount of borax used. Seasonal effects on the nitrogen and boron levels in the leaf were noted.

Introduction

Boron deficiency in flue-cured tobacco has been observed in a number of crops in the Nelson district. It has occurred mostly on soils of a granite origin, and, in some cases at least, it has been brought on by the injudicious use of lime. The symptoms of severe deficiency are a stunting of the plant caused by a shortening of the internodes. The leaves become thickened and enlarged and the plant takes on a bushy appearance, while the growing point shows a characteristic twist to one side and dies. The lateral growths produced after topping die back. In less severe cases the plant grows to maturity but the flower head is small and no seed is set. The upper leaves of the plant turn pale green in colour particularly at the base and the tips curl downward and inwards.

Review of Literature

The first observation of boron deficiency of tobacco in the field was made by Kuijper[2] in Sumatra in 1930. Swanback[6] and McMurtrey[4], working independently with solution cultures, both showed that boron is essential for the growth of the tobacco plant. Later, McMurtrey[5] reported boron deficiency symptoms occurring in the field in Maryland tobacco. Matthews and McVickar[3] working at Chatham, Virginia, with flue-cured tobacco recorded an increase in yield and quality from the use of 2½ lb. borax per acre, but warned against exceeding this amount. Boron deficiency brought about by excessive liming on soils of the Research Station has also been reported previously[1].

Soil

The Station soil is a medium to coarse "Umukuri" sand 9 to 10 inches deep overlying sand and gravel. It is derived from the "Kaiteriteri" series and is chiefly of granite origin. It has a low cation-exchange capacity and is naturally low in phosphate and potash. Symptoms of boron deficiency have been induced on it by liming.

Method and Layout

To determine the effect of applying boron to flue-cured tobacco under the conditions prevailing at the Station, trials were commenced

in 1947 and continued for five seasons. Three levels of borax were included, 0, 5, and 10 lb. per acre. All plots received the same basic fertilizer treatment, viz, 1,000 lb. of 3-8-8 (NPK) mixture per acre. Where borax was used it was thoroughly incorporated in the fertilizer prior to application. Half the fertilizer was applied before planting and half as a side dressing three weeks later.

The trial, using Harrison's Special variety, was carried out under a system of continuous tobacco culture, a cover crop of ryecorn being grown each winter and ploughed under in the spring. It was laid down in randomized blocks with six replications.

RESULTS

Yields of cured leaf in pounds per acre covering the five years of the experiment are given in Table 1.

TABLE 1. YIELD OF CURED LEAF (lb./ac.)

Treatment	1947–48	1948–49	1949–50	1950–51	1951–52	Average
Control	948	1121	1204	1356	1011	1128
5 lb. Borax	1109	1087	1196	1402	934	1146
10 lb. Borax	936	1113	1210	1261	959	1096
Sig. Diff. 5%	159	228	93	207	119	

The only significant difference is in the first year of the trial when 5 lb. of borax resulted in a yield significantly better than no borax or borax at 10 lb. per acre. Yields in subsequent years were very similar and somewhat irregular. Over the whole period of the experiment the plot receiving 10 lb. of borax has given the lowest yield although the difference is not significant. In the second, third, and fifth year of the trial it was noted that the tobacco on the plots receiving 10 lb. of borax was slower in getting away than the tobacco on the other plots. Although the difference in growth appeared to be made up by the end of the season, these plots were slightly later in maturity. At harvesting time the leaf from the plots receiving borax, especially at 10 lb. per acre, was markedly tougher to pick than the leaf from the control plots.

TABLE 2. EFFECT OF BORAX ON QUALITY

Treatment	Leaf Index				Acre Index			
	1949–50	1950–51	1951–52	Average	1949–50	1950–51	1951–52	Average
Control	226	344	326	299	226	381	279	295
5 lb. Borax	247	386	375	336	248	450	294	331
10 lb. Borax	247	395	350	331	253	414	279	315

As a matter of interest, some rows of tobacco adjacent to the experiment received borax at the rate of 40 lb. per acre as a side dressing when the crop was about half grown. This resulted in a checking of the growth and a distinct bronzing of the leaves. These leaves were extremely tough to pick.

In Table 2 are shown the leaf index and the acre index for the last three years of the experiment. It will be seen that both rates of borax have consistently improved the quality of the leaf, the 5-lb. application giving as good results as the 10-lb. rate. This improvement was brought about by an increase in the percentage of bright grades on the borax-treated plots, and also by an improvement in the texture of the leaf, which was finer and silkier. In addition there was less ragged and damaged leaf from the borax-treated plots.

ANALYTICAL DATA

In all five seasons of the experiment, samples, on a weighted basis to represent the whole crop, were taken for chemical examination. The lamina was separated from the midrib in the preparation of the samples for analysis. Chemical determinations covered total reducing sugars, sucrose, total nitrogen, and boron contents.

Data for reducing sugars contents are given in Table 3.

TABLE 3. REDUCING SUGARS PER CENT OF DRY MATTER

Borax (lb./ac.)	1947–48	1948–49	1949–50	1950–51	1951–52	Average
0	25.1	23.7	n.d.	23.1	21.9	23.4
5	21.6	24.2	n.d.	n.d.	22.1	22.6
10	23.4	24.4	n.d.	22.8	21.5	23.0

These data show that the use of borax at the stated rates exerted very little influence on the reducing sugars content of the leaf. The full data for sucrose are not presented here, but the average content was about 3%. Borax treatments had no certain effect either on the figures for sucrose for individual seasons or on the average figure. Smoking quality, as judged by sugar content should not have been affected by the use of borax.

A second measure of quality, namely total nitrogen content, is reported in Table 4. The results are given as percentages on the dry matter basis.

TABLE 4. TOTAL NITROGEN PER CENT OF DRY MATTER

Borax (lb./ac.)	1947–48	1948–49	1949–50	1950–51	1951–52	Average
0	1.67	1.42	1.86	1.74	1.53	1.64
5	1.86	1.44	1.89	n.d.	1.56	1.69
10	1.80	1.42	2.04	1.63	1.58	1.69

Variation in nitrogen content has been influenced more by seasonal conditions than by use of borax. Except in the 1947–48 and 1949–50 seasons borax treatment has had little effect on the nitrogen content. The average figures show that use of borax has only slightly raised the nitrogen content, but the amount is small and is probably not significant in view of the within-season variations.

It may be noted that when borax was used in the 1949–50 season at 40 lb. per acre the nitrogen content of the crop was 1.83%, thus being slightly below the level of the no-borax material.

Boron contents of the leaves were appreciably affected by the applications of borax. Data for boron content of laminae are given in Table 5.

TABLE 5. BORON (p.p.m. D.M.) IN LAMINAE

Borax (lb./ac.)	1947–48	1948–49	1949–50	1950–51	1951–52	Average
0	16.0	17.9	18.1	21.3	14.7	17.6
5	33.9	32.5	46.1	n.d.	45.0	39.4
10	44.5	47.5	67.0	43.8	65.3	54.6

It is noticeable that in the first two and in the fourth seasons the use of 10 lb. of borax per acre has raised the boron content by about 28 p.p.m., even though the level in the no-borax leaves varied somewhat; in the other two seasons the increase was 50 p.p.m. What the factor is that has caused these two levels of increase to appear is not clear. In all seasons the boron level of the treated plants was greatly increased, the increase being almost directly proportional to the amount of borax used.

In two seasons 1947–48 and 1949–50 the boron contents of the midribs of the leaves were determined. The results were as follows:

TABLE 6. BORON (p.p.m. D.M.) IN MIDRIBS OF LEAVES

Borax (lb./ac.)	1947–48	1949–50
0	17.0	22.7
5	27.9	32.5
10	28.1	33.1

These figures show that in the untreated plants the levels of boron are nearly the same in laminae and midribs, but that, although use of borax has increased the boron content of the midribs, the increase in boron content of midribs has been much less than in the laminae. Moreover there is not much difference in the boron content of the midribs at the 5 lb. and 10 lb. levels. This resistance of the midribs to build up high concentrations of boron is shown by data from plants which in the

1949–50 season received borax at 40 lb. per acre; in this case the midribs contained only 51.0 p.p.m. of boron whereas in the laminae there was a level of 166 p.p.m.

DISCUSSION

The addition of borax to the fertilizer has given somewhat irregular results although the general trend has been towards an increase in yield. There was no doubt about an improvement in the quality of the cured leaf and the handling of the crop in the field. It would appear that brittle varieties of tobacco like Virginia Gold can be appreciably improved in handling by the addition of a small quantity of borax to the fertilizer. The level of borax to be used may be fairly critical. While 5 lb. per acre appeared to be ample for the requirements of the crop, 10 lb. not only brought no additional benefit but resulted in retarded growth and delayed maturity. As this occurred in three of the five years and not in the other two the meteorological records covering the period of the trial were examined. Rainfall in hundredths of an inch for the months of October, November and December are given in Table 7.

TABLE 7. RAINFALL FOR OCTOBER, NOVEMBER, AND DECEMBER
(Falls above and below the 15-year average are indicated by + and —)

Year	October	November	December
1947–48	766 +	289 —	594 +
1948–49	315 —	461 +	46 —
1949–50	253 —	532 +	376 +
1950–51	220 —	36 —	632 +
1951–52	659 +	573 +	337 —
15-yr. average	439	308	367

The two seasons 1947–48 and 1950–51 in which no check to the tobacco was observed were both years with a relatively dry November followed by heavy rains in December. The distribution of rainfall in the other three seasons where a check to the early growth and a delay in maturity occurred was strikingly the reverse. In these years the November rainfall was well above the average while that for December was average or below. The relation between rainfall and retardation of growth, while consistent in pattern is not quite clear. It might be expected that in a wet planting season there would be a greater dilution of the boron in the soil solution and hence less adverse effect on the plants. However it is well known that under dry conditions a tobacco plant roots out more extensively and vigorously than under conditions of abundant moisture and it may well be that this more extensive root system is subjected to a lesser concentration of boron than is the restricted root development present in a wet planting season. The data for boron content of the leaves do not bear this out however. As has already been noted more boron was absorbed in the 1949–50 and 1951–52 seasons than in the others; both of these were seasons with a high November rainfall, but were of opposite character in December, the former being a wet season and the latter a dry one.

Seasonal conditions have not greatly affected the level of reducing sugars in the leaves. On the other hand the level of nitrogen has been reduced in the 1948–49 and 1951–52 seasons which were dry in December, and increased in the 1949–50 season which was unusually wet.

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EFFECT OF FREQUENCY AND TIMES OF CUTTING ON TWO COMMERCIAL "STRAINS" OF PAMPAS GRASS (*Cortaderia selloana*)

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(Received for publication, 24 July 1956)

Summary

Yield trials with two "strains" of pampas are recorded. The heaviest yield was obtained from cutting in alternate years but the quality of the pampas was low.

Cutting twice yearly over a number of years weakens the plant to such an extent that production falls to a very low level. Pampas will not tolerate frequent defoliation and grazing once a year combines high yield with permanence.

Summer cutting gave the highest yields of the annually cut treatments.

The results of chemical analyses of pampas at different stages of growth are given.

"Strain M" gave approximately double the yield of "Strain T" over all treatments.

Introduction

It is not widely realized that pampas grass, despite its size and high potential yield, is very readily affected by the treatment it is given. In a previous paper[1] it was shown that early cultivation sufficient to control weed growth was beneficial and that the application of fertilizers led to increased yields. A further trial to test the reaction to cutting of the two principal commercial "strains" on the market in New Zealand was commenced in 1950 and continued until 1955. Cutting was started in January 1952.

During the first two years of the trial, the plants were cut with a hand saw and weighed immediately, the cut being made at approximately 9 in. from ground level. In the last two years a machine designed specially for cutting pampas by Mr. M. W. Cross of this College was used and this gave a more uniform cut also at 9 in. from ground level. Green weights only were recorded, for the work of effective sampling of the leaves, leaf bases, stems, and flowers of so many large plants was beyond the means of the staff and facilities available. While there is a possibility of some bias due to recording only the green weights, the differences between treatments are distinct enough to allow for satisfactory conclusions to be drawn.

The Commercial Strains

Two "strains" were used in this trial. One of them has been derived from a single selection of a female plant and is propagated by means of clones—this to be referred to in the text as "Strain M". The other has been propagated from seed obtained by open pollination, the seedlings being grown on in the nursery and broken up into clonal groups for planting; this to be referred to in the text as "Strain T". Both strains were purchased directly from the nurseries concerned.

Soil Type

The soil on which the plots were situated is of recent origin, light in texture and not fertile. It is on a recent accretion of the Manawatu River and is still liable to flood. It is classified as Manawatu Sandy Loam derived from Alluvium (Soil Set No. 1, *N.Z. Soil Bur. Bull. n.s. 5. 1954).*

LAYOUT OF THE PLOTS

Six replications of a 5 × 2 split-plot design were laid down, the main plots being allotted to cutting treatments. Each main plot consisted of a 9-plant row of each strain, M and T, as sub-plots. Plants were set at 6-ft. centres each way and a border row was provided for each pair of replications.

The plots referred to in the analyses consist of 9 plants (or the number of survivors from these) of one or other of the strains.

Planting

Plants were watered before being planted in cultivated ground on 12–13 September 1950. For almost 3 weeks there was no rain, but establishment was good. On 26 October 3% of Strain T and 4% of Strain M had to be replaced, but subsequently the mortality rose to 67 plants out of 540 (over 12%, mainly in Strain T). The land was cultivated several times until May 1951, after which the ground was allowed to develop its own sward.

Treatments

Cutting treatments were due to commence with the spring cut (October) in 1951, but this cut had to be delayed until the time of the summer cut (January 1952). Plants were thus 16 months old before the first cutting treatment was started.

The cutting treatments were as follows:

(1)	Every two years	July
(2)	Every winter	July
(3)	Every summer	January
(4)	Every spring	October
(5)	Winter and summer	July and January.

Cutting was continued at the specified dates until the final spring cuts were made in October 1955.

All plants were put out at the same time, but, because they had to be cut at 3 different periods in the year, there is a difference in the age of the plants at the time of cutting. This difference in age is likely to have more marked effect on the yields from developing plants than those that are more mature and for this reason most stress has been placed on the results of the last two years of the trial.

RESULTS

First Two Years

By the end of the second year, differences due to treatment were appearing. Because of the great variability and the large number of

missing plants (67 in 540), the block differences have been ignored and the plants of Strain M grouped into one experiment of 5 treatments and Strain T into another with the same treatments. The mean yields per plant for the first two years and their standard errors are as given in Table 1.

TABLE 1. TREATMENT MEANS FOR THE FIRST TWO YEARS OF THE TRIAL
(green weight per plant in lb.)

Treatment	Strain M	Strain T
(1) Cut every 2 years	101.0 ± 4.4	46.9 ± 3.1
(2) „ „ winter	66.7 ± 4.2	31.1 ± 3.2
(3) „ „ summer	54.5 ± 4.1	28.6 ± 3.2
(4) „ „ spring	37.8 ± 4.3	16.6 ± 3.2
(5) „ „ winter and summer	57.3 ± 4.1	26.7 ± 3.1

The differences between any pair of means significant at the 5% (1%) levels of probability approximate 11.9 (15.7) for Strain M, and 8.8 (11.6) for Strain T respectively; "approximate" because the differences change with the comparison made, but so slightly that the average differences given above can be used for all comparisons.

Conclusions for the First Two Years

(a) The yield from plants cut at the end of the first 2 years of the trial was significantly greater than the yield from any other treatment.

(b) The yield from plants cut every spring was significantly less than the yields from all other treatments.

(c) The yields from the remaining treatments did not differ significantly.

The results for the two strains followed parallel lines. The difference between the yield of strains at any cutting interval was marked and "Strain M" was superior to "Strain T" at all cutting frequencies

Last Two Years

Separate analyses were performed for each strain using the mean weights of plants in each plot and a combined analysis was done to check any strain x cutting-frequency interactions.

A summary of the analyses of variance and treatment means for the second 2 year period is as follows.

Conclusions for the Last Two Years

(a) There was no strain × frequency interaction, i.e. the responses of the plant to changes of treatment were similar in the two strains.

(b) There was no significant difference in either strain between the per-plant yield under 2-year cutting or cutting every summer only.

(c) Both the 2-year cuts and cutting every summer only were significantly higher than those obtained under any other treatment.

TABLE 2. ANALYSES OF VARIANCE AND TREATMENT MEANS FOR THE LAST TWO YEARS OF THE TRIAL
(green weight per plant in lb.)

Source of Variation	d.f.	Mean Squares and Results of F Tests		
		Strain T	Strain M	Combined
Replications	5	947.54	1408.16	1999.36
Treatments	4	2408.38**	4346.50**	6403.27**
Error (1)	20	264.49	288.03	360.54
Strain	1			12298.00**
Tr. × Strain	4			355.83
Error (2)	25			224.09
Total	59			
Coeff. of variation		39.8%	24.5%	27.1%

Treatment	Strain T	Strain M	Combined
(1) Cut every 2 years	55.0 ± 6.7	95.5 ± 6.9	75.0 ± 5.5
(2) „ „ winter	32.0	62.0	47.0
(3) „ „ summer	65.5	88.5	77.0
(4) „ „ spring	37.5	74.5	56.0
(5) „ „ winter & summer	14.0	27.0	20.5
Sig. diff. at 5%	19.6	20.4	16.2

The overall variety means and the SEs were:
Strain T 40.9 ± 2.8
Strain M 69.5 ± 2.8

(d) The yields from cutting in winter only and in spring only did not differ significantly.

(e) The yields from cutting twice a year (winter and summer) were significantly lower than for any other treatment.

These results can be best summarized by stating that the 5 treatments fit into the following 3 groups, all significantly different from the others

(1) Two-yearly, and summer cutting.

(2) Annual winter and spring cutting.

(3) Twice-yearly cutting.

One possible explanation for the high weights of the summer cuts is that the flower stalks (which emerge from the sheath in February) contributed an appreciable weight. By the time the winter cut was made, these had dried off and contributed little to the weights. The spring

cut was made too early for the stalks to influence the weights to any great extent, if at all.

Work at Massey College has shown that 32–35% of the green weights of plants cut on 19 February was made up of flower stalks and the leaves attached to them. By winter time the stalks had dried up and the leaves associated with them had (mainly) died.

Treatments 2–5 Only—Last Three Years

It is clear that treatments 2 to 5 are the ones most likely to concern farmers who are feeding pampas to their stock. By considering only these 4 treatments it is possible to examine the data for the last 3 years of the trial year by year and strain by strain.

TABLE 3. ANALYSES OF VARIANCE AND TREATMENT MEANS FOR THE SECOND YEAR OF THE TRIAL FOR TREATMENTS 2–5 ONLY
(green weight per plant in lb.)

Source of Variation	d.f.	Mean Squares and Results of F Tests	
		Strain T	Strain M
Replications	5	26.38	108.71
Treatments	3	130.21**	336.44**
Residual	15	21.02	55.80
Total	23		
Coefficient of variation		27.7%	22.2%

Treatment	Strain T	Strain M
Cut winter only	21.8 ± 1.9	40.1 ± 3.1
Cut summer only	18.3	36.5
Cut spring only	15.2	35.4
Cut winter and summer	11.0	22.9
Sig. diff. at 5%	5.7	9.2

Taking the above results for Treatments 2–5 together, it can be seen that in both strains treatment differences became more marked with each year, until by the final year of the trial the treatments all differed significantly in the order: Summer only, Spring only, Winter only, Summer and winter. The last treatment (cutting twice yearly) was significantly lower than all others at all stages after the first year of the trial.

Interactions Frequency × Strain. A combined analysis for each year's data was made to examine the interactions between frequency and strain, but because of the differences in strain yields and variances, a transformation of scale was necessary. Since coefficients of variation tended to be the same in the two strains, the indicated transformation was the logarithmic transform. Differences in the log. scale would correspond to ratios of plant weights on the true scale.

TABLE 4. ANALYSES OF VARIANCE AND TREATMENT MEANS FOR THE THIRD YEAR OF THE TRIAL FOR TREATMENTS 2–5 ONLY
(green weight per plant in lb.)

Source of Variation	d.f.	Mean Squares and Results of F Tests	
		Strain T	Strain M
Replications	5	192.74	239.85
Treatments	3	497.04**	723.66**
Residual	15	54.45	63.13
Total	23		
Coefficient of variation		36.4%	32.9%

Treatment	Strain T	Strain M
Cut winter only	22.0 ± 3.0	43.1 ± 3.3
Cut summer only	31.1	37.5
Cut spring only	19.1	37.4
Cut winter and summer	9.0	18.1
Sig. diff. at 5%	9.1	9.8

TABLE 5. ANALYSES OF VARIANCE AND TREATMENT MEANS FOR THE FOURTH (FINAL) YEAR OF THE TRIAL FOR TREATMENTS 2–5 ONLY
(green weight per plant in lb.)

Source of Variation	d.f.	Mean Squares and Results of F Tests	
		Strain T	Strain M
Replications	5	230.32	303.16
Treatments	3	984.54**	2081.60**
Residual	15	124.30	92.26
Total	23		
Coefficient of variation		65.0%	33.1%

Treatment	Strain T	Strain M
Cut winter only	10.5 ± 5.0	18.5 ± 4.0
Cut summer only	34.5	51.0
Cut spring only	19.0	37.0
Cut winter and summer	3.5	9.5
Sig. diff. at 5%	13.7	12.1

TABLE 6. SUMMARY OF ANALYSES OF VARIANCE FOR THE LAST THREE YEARS FOR TREATMENTS 2–5

(log. green weight per plant in lb.)

Source of Variation	d.f.	Mean Squares and Results of F Tests		
		2nd Year	3rd Year	4th (final) Year
Replications	5	0.0244	0.0989	0.1542
Treatments	3	0.1905**	0.4116**	1.3163**
Error (1)	15	0.0199	0.0113	0.0221
Strains	1	1.2926**	0.8419**	0.8454**
Treatment × strain	3	0.0060	0.0144	0.0047
Error (2)	20	0.0157	0.0176	0.0103
Total	47			

The above analysis reaffirms the highly significant treatment effects in each year of the trial, shows the highly significant differences between the strains in each year, and in the Interaction line of the table shows that in no year was there any interaction between strain and frequency of cutting on the log. scale. That is, in every year of the trial the yields of the two strains were in a virtually constant ratio regardless of the treatment imposed. For instance in almost all years and frequencies of cutting, the yield of Strain M was about double that of Strain T. Even where the drastic twice-yearly cutting reduced the yield of Strain M to 9.5 lb. per plant in the last year of the trial, the corresponding yield of Strain T plants was only 3.5 lb.

Survival of Plants

Despite the severe defoliation treatments where the entire leafage was removed and the plants were cut to 9 in. from the ground level, only 2 plants failed to survive (Strain T summer only). It is clear however, that had the trial been continued the position would have changed radically, especially so in the treatment where the plants were cut twice a year.

Effect of Stage of Cutting on Chemical Composition

There is evidence in grasses generally of a trend towards a higher fibre content and a lowering in feeding value as leaf growth becomes more mature.

The following table gives the results of analyses of pampas grass made at Massey Agricultural College.

It is clear that (with one exception) the crude-protein content is highest in the young growth and least in the 2-year growth and that the reverse holds for crude fibre. While the above periods at which samples were taken do not coincide with the time the cuts were made, they show the trends for protein and fibre with increasing age.

TABLE 7. ANALYSES EXPRESSED ON DRY-MATTER BASIS AS PERCENTAGE OF OVEN-DRY WEIGHT

Sample No.	Crude Protein	Ether Extract	N.F.E.	Crude Fibre	Total Organic Matter	Total Ash	Insol. Ash
1	9.6	1.9	43.5	38.1	93.1	6.9	3.2
2	8.2	1.8	39.8	42.3	92.1	7.9	2.9
3	8.2	1.3	42.0	39.2	90.7	9.3	3.9
4	8.9	1.4	44.6	35.0	89.9	10.1	4.8
5	5.5	1.9	39.9	47.3	94.6	5.4	2.5
6	6.9	52.3		34.8	94.0	6.0	
7	7.6	50.0		33.4	91.0	9.0	
8	8.3	1.4	47.0	36.1	92.8	7.2	2.8
9	5.8	56.3		32.8	94.9	5.1	

Origin of Samples:

1. 4-yr.-old strain T plant— 4 months' leaf growth
2. „ „ T „ 8 „ „ „
3. „ „ M „ 8 „ „ „
4. „ „ M „ 12 „ „ „
5. „ „ T „ 24 „ „ „
6. „ „ T „ 12 „ „ „ (narrow leaf)
7. „ „ M „ 12 „ „ „ (broad „)
8. Plumes only—after emergence
9. „ and stalk—plumes just emerging.

DISCUSSION

The method employed in this trial was to cut the plants at specified periods to a height of 9 in. from ground level. The treatment was not unduly drastic, for yields continued to rise under some of the treatments in the third and fourth years of the trial. It is considered that, where yields declined, the treatments imposed were, with the following exception, responsible. The final cut in the winter-cut series showed a big drop in yield and it is thought that the frosts which caused a browning of the recovery growth were responsible for this. The method of cutting adopted left no protective covering for the recovery growth such as one finds where the crop has been grazed off with cattle.

Yields for the first two years gave no indication of the true response to the treatment imposed, for the plants were at that time not fully grown even though they had been in the ground for 16 months before the first cutting. Consequently most cognisance has been given to the results from the final 2 years of the trial.

The soil was not ideally suited to pampas growth. The drainage was good but fertility low. The figures obtained for yield are below those that have been obtained on better soil on the same farm.

Cut Every Second Year. Despite the fact that this treatment gave a significantly higher yield than all other treatments at the first cut and was only equalled by the summer cut in the second 2-year period, this is not a satisfactory method of treating pampas grass. The crude

fibre is high and the protein low and experience elsewhere has shown that cattle are loth to eat it and are likely to starve themselves voluntarily before doing so.

Cut Every Winter. During the first two years this treatment gave high yields, but the increases found in the second 2-year period in the summer- and spring-cutting treatments were not noted in the winter-cut series. It is conjectured that frosts may have been responsible for this as some frost damage was noted in the recovery growth after the third yearly cut.

Winter is the general and logical time to utilize pampas for cattle, as the overall feed supply is usually at its lowest then. Under normal grazing with cattle, there is protection for the regrowth in the litter left on the butt. The method of cutting in this trial involved the removal of all material more than 9 in. from the ground and left the regrowth liable to damage from heavy frosts. Only in the one season however was this frost damage noticed.

Cut Every Summer. Some farmers wish to utilize pampas in summer, particularly so when the feed from pastures is curtailed by drought. Summer yields from the first two cuts were high and not significantly different from those of the winter cuts. As the plants matured and produced more and heavier flower stalks, the yields of the summer cuts increased until they became comparable to those of the 2-year cuts. From other trials using mature plants, it was found that from 32–35% of the green weight was made up of flower stalks and the leaves attached to them in mid February (1 month later than the summer cutting date in these trials). Such high percentages would not be obtained in the present trial, but even so there would accrue a considerable advantage in weight and this is shown in the figures for the last two years. The quality of feed provided by the flower heads is relatively good and the plumes are eagerly sought by stock. While the protein content of the stalks and plumes is not high, the fibre content is relatively low.

Cut Every Spring. In the first two years the yield from plants cut every spring was significantly less than the yields from all other treatments with the exception of that cut twice yearly. The final two years however, showed a relative improvement and, in the final year, yield was next to that of the summer cuts in treatments 2–5.

Pampas is not normally utilized in spring, nor is it likely to be, unless some radical change in pasture technique eventuates.

Cut Twice a Year (Summer and Winter). At the end of two years of treatment the yields were relatively high and did not differ significantly from those of the winter and summer cuts and were significantly (5%) better than those from the spring cuts.

The final two years however saw a rapid and very marked decline in relative and actual yields when the yields were significantly lower than from any other cutting treatment. This effect was becoming evident by the end of the second year.

It is possible that this treatment was adversely affected by frosts in the same way that the winter-cut series was in the third year's cutting, though this is not shown in the yields for that season.

Effect of "Strain". There were highly significant differences between the yields of the two strains in every year. Under all treatments

Strain M outyielded Strain T. A fairly constant relationship was maintained between them during the two 2-yearly periods with the exception of the summer cut in the second year when there was a rise in the relative yield of Strain T. This can be accounted for by the increase in size and weight of the flower heads and stalks that came into this cut, and, as the numbers of these in both strains were not greatly dissimilar, the yields tended to be more even than in other treatments. Strain M was ahead in yield in the ratio of about 2:1 in all those cuts where leafage contributed solely (or almost so) to the weight. It is possible that under different environmental conditions Strain M may not show up so favourably as it did here. The results as given must therefore be taken to apply to yields on light soils in central Manawatu. There is evidence however, that Strain M has outyielded Strain T on other soil types and under warmer climatic conditions.

Effect of Age on Quality as Determined by Chemical Analysis. The constituents that concern the farmer most in feeding pampas are crude protein and fibre content.

Dunlop and Coup[2] have shown that, when pampas was fed to Jersey cattle, the digestibility of protein and organic matter declined with the increase in age of the cut material. The stage of growth of the plant showed a definite and consistent relation to nutritive value, material cut at three months of age being superior to six months growth and both better than twelve months growth. The fall in quality under annual cutting was sufficiently large for them to consider a recommendation that pampas should be cut (or grazed) twice a year.

Results in this trial show that this may be satisfactory only on a short-term basis and not as a general practice. Yield figures showed that at the end of the first two years of cutting, two cuts per year gave yields comparable to those from the annual cutting treatments. Figures taken during the second 2-year period, however, showed that cutting twice a year gave yields less than half those of the poorest annual cut in both strains and these differences were highly significant. It would appear then that should the feed conditions on the farm in any one year warrant feeding off twice in that year this would not materially reduce successive yields provided the plants were given a 12-month period of growth following on this to recover from it.

For feeding purposes, trials at Ruakura have established that pampas is very similar to hay in dry matter composition and digestibility.

It is obvious that the protein content of the feed need not be high at the time of the year it is normally fed off, because the cattle feeding it have, or should have, a run-off on a grass pasture. Furthermore, as this crop is becoming more used for beef cattle and less for dairy cattle, the emphasis on protein content should not be overstressed.

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A NOTE ON FUNGICIDE SCREENING FOR CONTROL OF TOMATO LEAF-MOULD

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Summary

Of seventeen fungicides tested in the glasshouse for control of *Cladosporium fulvum* Cke., dichlone, zineb, captan, salicylanilide, and chloranil proved the most effective.

Introduction

Leaf mould (*Cladosporium fulvum* Cke.) first recorded in New Zealand by Kirk (1896) is a serious disease of tomatoes grown under glass. Regular applications of salicylanilide were found to prevent leaf-mould establishment (Chamberlain *et al.*, 1937). As this compound was not effective in control of other diseases affecting glasshouse tomatoes, growers were anxious to know to what extent other fungicides used in their plant-protection practices controlled this disease. Tests here described were carried out as part of the Division's certification scheme to measure the effectiveness of a number of these materials in control of leaf mould.

Materials

The following materials were tested:—

Copper compounds: Blitox (50% copper oxychloride) w.p.; Blue Ammon (4.5% copper ammonium sulphate) liquid; Bordeaux mixture; Fungex (8.5% copper ammonium carbonate) liquid; and Saline Colloidal Copper (15% copper oxychloride) emulsion.

Dithiocarbamates: Dithane D-14 (tank formulated zineb prepared by mixing 2 lb. 19% nabam + 1 lb. zinc sulphate + ½ lb. hydrated lime in 100 gal. water); Dithane Z-78 (65% zineb) w.p.; Dithane M-22 (70% maneb) w.p.; Fertram (80% ferbam) w.p.; Fuclasin Ultra (70% ziram) w.p.; and Tetram (80% thiram) w.p.

Miscellaneous compounds: Crag 341C (34% glyodin) liquid; Nirit (45% sulfocyano dinitrobenzene) w.p.; Orthocide (50% captan) w.p.; Phygon XL (50% dichlone) w.p.; Shirlan A.G. (25% salicylanilide) paste; and Spergon (48% chloranil) w.p.

Experimental Methods

One-month-old tomato plants grown in 6-in. pots were used throughout. Five plants per treatment were sprayed with a total of 150 ml. of fungicidal suspension. Twenty-four hours later, plants were inoculated by spraying with a spore suspension containing 10-15,000 spores per ml. and placed in a humidity cabinet (90% ± 1% relative humidity at 72 ± 2°F.) for 36 hours. Plants were then moved to a glasshouse held at 71 ± 5°F. Lesion counts were made 25 days later on all leaflets from two leaves per plant.

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RESULTS

Under these test conditions, fungicides (at the lowest effective concentrations per 100 gal. water) showed different degrees of effectiveness and were grouped as follows:

Those allowing production of 0-4 lesions per leaf, that is not significantly different from 0: Dithane D-14 (2 lb./1 lb./0.5 lb.); Dithane Z-78 (4.5 lb.); Phygon XL (0.5 lb.); Spergon w.p. (1 lb.); Orthocide (2 lb.), Shirlan A.G. (4 lb.), and Dithane M-22 (4.5 lb.).

Those allowing 5–9 lesions: Fuclasin Ultra (3 lb.), and Crag 341C (1.5 lb.).

Those allowing 10-30 lesions per leaf: Fertram (2.5 lb.), Nirit (0.5 lb.), Tetram (2.5 lb.), Bordeaux mixture (6 lb.: 8 lb.), Fungex (0.5 gal.), Blue Ammon (0.5 gal.), and Blitox (5 lb.).

All treatments gave significant reduction in the level of infection as compared with checks (108 lesions per leaf).

Three further tests were made with materials giving the best results with the exception of Dithane M-22 which caused severe plant damage.

Results in Table 1 confirm control obtained with materials previously selected.

TABLE 1. MOST EFFECTIVE TREATMENTS IN PREVENTION OF TOMATO LEAF-MOULD
(Means from 3 replications each of 5 plants)

Treatments	Amounts in lb. per 100 gal. water	Lesions per leaf	
		Mean No.	Log $(X + 1)$
Check—water	—	105.6	1.96
Phygon XL	0.5	2.7	0.33
Dithane D-14	2:1:0.5	3.1	0.38
Orthocide	2	5.4	0.57
Shirlan A.C.	4	7.0	0.60
Dithane Z-78	4.5	6.7	0.65
Spergon w.p.	1	7.4	0.67
Sig. Diff. at 1%:			0.46

CONCLUSION

Some fungicides (copper compounds, ziram, thiram and ferbam) used by growers for control of late blight, grey mould, and *Phoma* rot bring about a significant reduction in the incidence of leaf mould, but the degree of control is not as high as that given by some other compounds.

Under conditions of tests here described, dichlone at 0.025% (Phygon XL at 0.05%), tank formulated zineb (nabam at 0.04% + zinc sulphate at 0.1% + hydrated lime at 0.05%), salicylanilide at 0.1% (Shirlan A.G. at 0.4%), captan at 0.1% (Orthocide at 0.2%), zineb at 0.29% (Dithane Z-78 at 0.45%), and chloranil at 0.048% (Spergon w.p. at 0.1%) were the most effective treatments for control of leaf mould of tomatoes.

Acknowledgement

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THE COPPER CONTENT OF SOME SOILS AND PASTURE SPECIES IN CANTERBURY

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Summary

In a survey extending over two seasons, the copper contents of three members of a soil suite in North Canterbury, New Zealand, and of the pasture species growing on them, were determined.

The available copper in the soils, determined by the *Aspergillus* method, correctly distinguished between the abilities of the soils to supply copper to pasture species, and displayed a highly significant correlation with copper in white clover.

The copper content of white clover was consistently higher than that of ryegrass on all three soil types. The mean copper contents were 10.0 and 7.9 p.p.m. respectively. Seasonal differences in copper content of successive quarterly samples of green, leafy herbage, were considerable. Red clover and subterranean clover contained substantially more copper than white clover –averaging 12.3 and 11.8 p.p.m. respectively. All of the above differences were highly significant. Some pasture weeds were particularly high in copper, while mature (seeding) ryegrass was very low in copper. It is concluded that the older, more leached soils of the Canterbury Plains and downlands have an acquired deficiency in copper and may produce pastures at or near the deficiency level with respect to the copper requirements of livestock, but that the recognized methods of good establishment and management of pasture make the most effective use of the resources of copper in the soils.

Introduction

Copper deficiency in livestock in New Zealand has long been known, and much work has been carried out on various aspects of the subject. The amount of copper in a mixed pasture healthy for livestock was stated by Cunningham[1] to be 10–15 p.p.m. in the dry matter, while pastures deficient in copper range from 2.1–7.5 p.p.m. The widespread belief among farmers that with the development of improved pastures and more intensive farming the thrift of livestock was becoming an increasing problem, was easily linked with the thought that something must be lacking in the soil—some trace element. In Canterbury, attention became focussed on copper between the years 1948-51, and instances were reported from various parts of the province of benefits to crops and livestock from applications of copper salts; yet the accepted symptoms of copper deficiency were rarely in evidence. About this time the Soil Bureau and the Animal Research Station at Wallaceville were collaborating on a reconnaissance survey of the copper status of the major soil types of the country, and in 1951 Cunningham[2] presented a map, based on the soil map, showing areas known and suspected to be copper deficient for farm animals. He stated that on soils related to those known to be deficient, lowered livestock production might be occurring even though the deficiency was not sufficiently severe to produce the recognised clinical symptoms. It therefore seemed appropriate that a more detailed study of the copper content of selected Canterbury soil types and of the pastures growing on them should be undertaken. This paper presents the results of such investigation.

Recently, both molybdenum[3, 4, 5] and inorganic sulphate[6] have been shown to exert a controlling influence on the use made by the animal of its intake of copper; and, while these discoveries have modified the criteria by which the copper intake is judged as adequate or not, the possibility of incipient or absolute deficiency remains.

Since pasture which appears perfectly healthy and productive may nevertheless be deficient in some element essential for animal health, the study of such deficiencies involves a departure from the usual comparisons of dry-matter yields, and calls for a survey of the nutrient status of selected soils and of the pastures growing on them, together with some external evidence as to the levels to be adopted as marking the borderline of deficiency. For this reason no attempt was made in the present investigation to measure yields of herbage.

Copper Contents of Pasture Species

Omitting figures relating to soils deficient in copper for plant growth, there are yet many references to the nutrient status of pasture species wherein the copper contents are noted; and, although many figures are available for the copper content of mixed pasture growing in New Zealand[1, 3], Coop *et al.*[7] and more recently Wells[8, 9], seem to be the only workers in this country who have reported values for individual species. Both reported decreasing copper content of grasses as maturity increases, an observation which is confirmed by many other workers [10, 11, 12, 13, 14], while Coop *et al.* also reported white clover (*Trifolium repens*) and catsear (*Hypochaeris radicata*) as having higher copper content than grass species. Similarly Dick *et al.*[10] found that the copper content of subterranean clover (*Trifolium subterraneum*) was significantly higher than that of barley grass (*Hordeum leporinum*), while Thomas *et al.*[15] found herbs as a group significantly higher in copper content than grasses. Inherent differences between plant species have also been reported by Beeson *et al.*[14], Mitchell[16], Piper and Walkley[17], Moore[18], and Price *et al.*[19].

Plant and Soil Relationships

The relationship between copper contents of plants and soils has been the subject of much investigation. Teakle[20] and Teakle *et al.*[21], investigating pastures in areas deficient in copper for stock, found that subterranean clover could be used as an indicator of the copper status of the soil. They found low copper contents on sands and gravelly sands (as did Underwood *et al.*[22]) and much higher figures on loams. Cunningham[4] recognised that a large proportion of the New Zealand pastures deficient in copper occur either on coastal sands, leached silts, or peats; while Wells[8] reported considerable variation in the copper content of sweet vernal (*Anthoxanthum odoratum*) from different soil types. Beck[11] and Bennetts and Beck[23] also reported a pronounced effect of soil type. On the other hand, Piper and Walkley[17], while indicating a possible correlation of the copper content of oats with soil type, stated that copper in plants is more affected by species than by soil type.

Of recent years the *Aspergillus niger* method has been used by numerous workers as a means of assessing the amount of soil copper available to plants, and in some cases the values so obtained have been correlated with the incidence of copper deficiency in livestock. Thus,

Acock[24] suggested that 2.0 p.p.m. in the soil is the threshold figure, below which pastures are likely to be deficient in copper; while Wright[25], on the evidence available for New Zealand soils at that time, quoted 1.5 p.p.m. as the minimum safe level for mineral soils. More recently, R. H. Thornton (pers. comm.) suggested 2.0 p.p.m. as a tentative figure for the threshold value.

In studying soil-plant-animal relationships in New Zealand, Wright[25] and Taylor[26] have made effective use of the concept of the "soil suite", in which a number of soils from a common parent material are arranged in sequence of profile development. It is reasoned that any deficiency of the parent material itself will have been inherited by all members of the suite, whereas a deficiency exhibited only by the older members of the suite will evidently have been "acquired" as the result of weathering and leaching. The early recognition of such trends in the mineral status of related soils offers much saving of time and work.

The greater part of the soils of Canterbury has developed from very similar parent materials, the alluvium and loess derived from the greywacke of the central and eastern ranges of the Southern Alps. It therefore seemed appropriate to employ the "soil suite" concept in the present instance, and three soil types were selected, comprising three stages of development, ranging from recent alluvium near the coast to a moderately weathered and leached soil on the downlands which lie behind the gravel plains. Two transects through this suite of soils were selected, one north of the Waimakariri River, the other between the Selwyn and Rakaia Rivers. On the chosen sites, observations were made over a period of two years on the copper content of the principal pasture species as related to that of the soils, and as qualified by the passage of the seasons.

It was hoped thus to discover whether there was any evidence of actual or incipient copper deficiency either (a) within this area in general, or (b) confined to the older more leached soils, or (c) associated with particular pasture species or stages of growth. Finally it was hoped to obtain further evidence on the reliability of the *Aspergillus niger* method for the determination of available copper in soils.

EXPERIMENTAL

Soil Types and Localities

The salient characteristics of the three selected soil types and their location are shown in Table 1. All are derived from greywacke loess or alluvium, under a rainfall of 25 to 30 inches. Waimakariri silt loam, being one of the most recent and least weathered of the Canterbury soils, and of widespread occurrence along the banks of the rivers of the Plains, is of high natural fertility. It was expected to have retained more of the original stock of copper than the older, more weathered soils.

Eyre shallow silt loam, a soil of the "light Plains land", occurs on one of the higher terrace levels, which are well defined near the river gorges, though less obvious near the coastal lowlands. It is much older and more weathered and leached than the Waimakariri soil, as its stronger colours and chemical properties testify. Comprising a shallow horizon of sandy silt loam on deep, free-draining gravel, this soil has experienced more intense leaching than the annual rainfall would

normally effect, while its proneness to intense desiccation during summer months has limited the accumulation of organic matter. For these reasons it is classified as intrazonal, related to the yellow-grey earth, the zonal soil of the district[27]. Soils of this type have been likened by Vucetich[28] to free-draining yellow-brown earths during periods of ample moisture, and to desert-like soils during drought periods. It could be expected to be more depleted of copper than the Waimakariri soil.

Mairaki silt loam is a moderately leached zonal soil (yellow-grey earth) derived from deep loessial deposits on the gently rolling downlands contiguous with the upper fringe of the gravel fans of the plains. This soil is probably much older than the Eyre soil, and shows evidence in its somewhat brighter colours and compact pan formation of being more strongly weathered and leached. Mairaki soils are characterised by a compacted B horizon which, by restriction of the internal drainage, results in pastures being extremely wet in winter and late to commence growth in the spring. In most seasons improved pastures are much more productive than on the Eyre soils, and it would therefore be expected that under such pastures the build-up of organic matter in the topsoil would be correspondingly greater.

On these three soil types, areas of improved pasture, dominantly of ryegrass and white or subterranean clover, were chosen. In all, 18 sites were selected, three sites in each locality, giving six sites on each soil type. Selection was confined to improved pastures, since, as noted already, it was on such pastures that problems of thrift in livestock were alleged to occur; moreover it was hoped thereby to lessen the inherent differences in productive ability of the chosen soils.

TABLE 1. Description and Locality of Soil Types*

Soil Type	General Description	Type Profile	Localities
Waimakariri silt loam (W3)	Recent, well drained alluvial soil. Leaching and weathering slight. Natural fertility—high.	8 in. grey to dark grey silt loam On light grey sandy loam	Southbridge and Clarkville
Eyre shallow silt loam (E3s)	Young—immature alluvial soil, with loessial addition. Intrazonal, related to yellow-grey earths. Very free drainage. Droughty in summer. Natural fertility—low.	8 in. grey-brown stony silt loam. 10 in. light yellowish-brown stony silt loam. On gravels	Dunsandel and Swannanoa
Mairaki silt loam (Mi3)	Moderately leached yellow-grey earth. Poor internal drainage. Wet in winter. Late spring. Natural fertility —low-medium.	10 in. light brownish-grey silt loam. 7 in. pale grey-yellow silt loam (mottled). 12 in. pale yellow silt loam (mottled) on pale yellow silt conspicuously seamed with light grey veins.	Hororata and Mairaki Downs

* Names, symbols and type profiles by courtesy of N.Z. Soil Bureau; Bull. 14, "Soils and Agriculture of the Downs and Plains of Canterbury and North Otago, N.Z." (In press).

Procedure

On each of the selected sites, defined areas ten yards square were subjected to periodic sampling of soil and herbage for a period of two years. The sites were not fenced but were grazed by sheep in common with the rest of the fields on which they occurred. The grazing of the pastures was not always satisfactory, and growth became tall and stemmy at times. Samples were collected in October 1950, February, June, and October 1951, and January and April 1952, thus securing a measure of copper levels of herbage in the spring, summer, and late autumn, for two seasons. At one site on each soil type in each transect the soils were sampled initially at three depths 0–2 in. (12 cores per site) and at 8–10 in. and 36–38 in. Pits were dug when taking the deeper samples to preclude any risk of contamination. All other sites were sampled to the depth of two inches only. It was assumed that copper levels in the soil would not vary significantly during the period of the trial, and subsequent soil samples (0–2 in. only) were taken solely to obtain a measure of general fertility levels by routine quick-test methods. The available-copper content of the original soil samples was assessed by the *Aspergillus niger* method, using Mulder's strain. The technique followed was essentially that of Nicholas[29], using the medium at pH4, with the modification that the method of Donald, Passey, and Swaby[30] was used for the purification of the medium. Herbage samples from six random unit areas were cut on each visit, cutting everything to within half an inch of ground level by means of steel hand shears. No data on yields of herbage are reported, since the composition and grazing of the different pastures were not comparable. It was desired that as far as possible the herbage samples should be of green leaf and stem, but owing to lax grazing in a few cases more-mature seed-stalk constituted a large part of the sample.

The samples were sorted into their constituents according to the following classification:

(a) The ryegrasses (*Lolium* spp.) either perennial or short rotation.

(b) White clover (*Trifolium repens*).

(c) Subterranean clover (*T. subterraneum*).

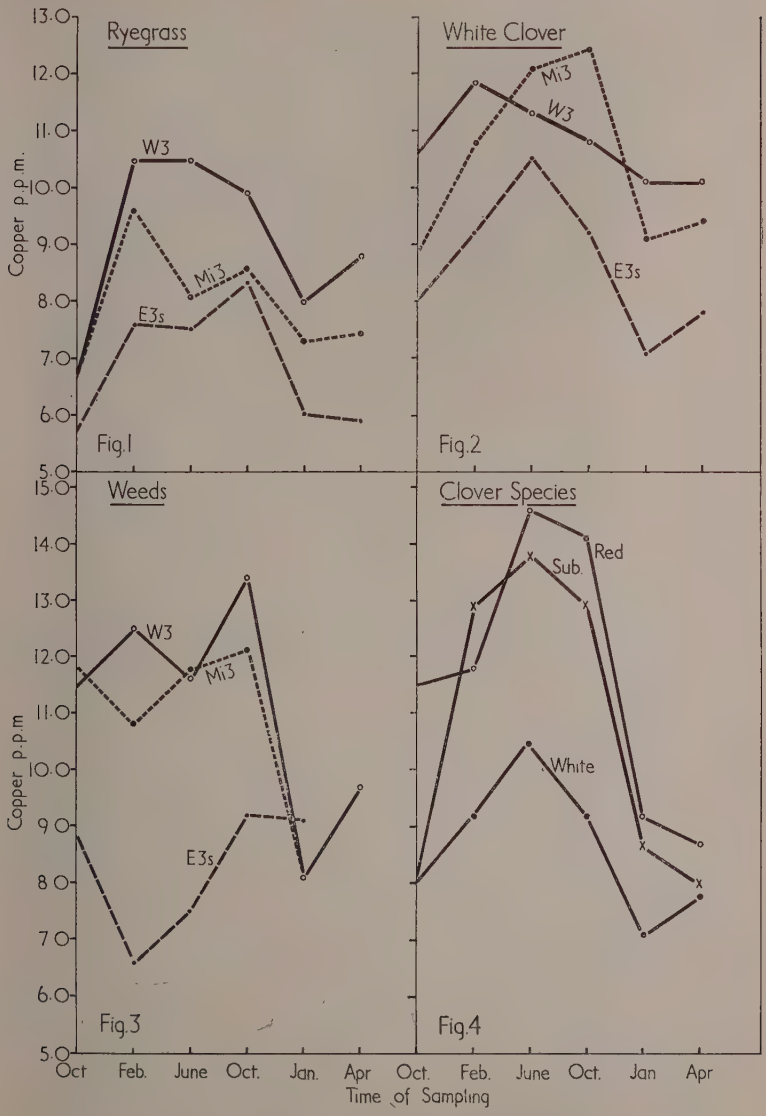
(d) Red clover (*T. pratense*).

(e) Weeds—weed grasses and flat weeds.

No subterranean clover was obtained from the pastures on the Waimakariri soils as, on account of their high fertility, this species had not been introduced here. Similarly, little of this species was found in the pastures on the Mairaki soils because of their better moisture status. Red clover was virtually confined to the pastures on the Eyre soils. Cocksfoot (*Dactylis glomerata*) was separated in a few cases when it constituted more than a few per cent of the total yield, while mature herbage was separated from young herbage in the cases of lax grazing. The ryegrass sub-samples, especially those from the Mairaki soils, occasionally included a small amount of crested dogstail (*Cynosurus cristatus*). The copper content of the dry matter of the above herbage separates was determined by the method of Clare, Cunningham, and Perrin[31].

TABLE 2. Copper Contents of Herbage Separates Grown on Three Canterbury Soil Types
(p.p.m. in D.M.)

Soil Type	Herbage Separate	Dates of Sampling						Means	
		Oct. 1950	Feb. 1951	June 1951	Oct. 1951	Jan. 1952	April 1952	By Soils	Seperates
W3	Ryegrass	4.6-9.2 (6)	8.2-14.6 (6)	6.9-12.4 (4)	7.6-11.0 (5)	6.6-10.4 (6)	6.4-16.2 (6)	9.0	7.9
E3s		3.8-7.8 (7)	5.7-9.1 (7)	6.4-8.6 (7)	5.0-10.5 (7)	5.4-6.3 (6)	5.0-7.9 (6)	6.8	
Mi3		4.4-8.6 (6)	8.3-11.5 (6)	6.3-8.8 (6)	6.9-10.0 (6)	5.9-8.5 (6)	6.3-8.3 (6)	7.9	
W3	Ryegrass at seeding or reseeded		3.2-3.4 (2)	4.7		3.3-4.4 (5)	4.7	4.0	3.5
E3s			1.8		3.3	2.7-3.1 (4)	2.3-3.1 (3)	2.7	
Mi3						2.8-5.0 (6)		4.0	
W3	White clover	8.7-12.1 (7)	10.0-13.8 (6)	8.3-16.5 (5)	10.1-13.5 (6)	8.3-12.6 (6)	7.5-12.7 (6)	10.8	10.0
E3s		7.2-9.9 (6)	8.0-10.5 (5)	8.6-12.2 (6)	7.2-11.3 (6)	4.9-9.1 (7)	-	8.6	
Mi3		7.4-10.5 (6)	9.3-12.7 (6)	11.0-13.5 (6)	9.7-13.3 (6)	7.8-10.5 (5)	9.2-10.1 (5)	10.5	
W3	Subterranean clover	6.1-11.4 (6)	12.2-15.8 (4)	11.1-15.8 (6)	10.6-15.3 (6)	9.6-11.5 (3)	7.5-8.4 (2)	11.2	11.8
E3s		11.7-12.2 (2)	17.1	11.6-12.5 (2)	14.8-15.0 (2)	14.0	14.5-15.6 (2)	13.9	
Mi3									
W3	Red clover	9.6-11.7 (4)	8.3-16.1 (5)	12.4-16.0 (5)	8.9-16.8 (6)	5.5-11.9 (5)	6.7-10.7 (2)	12.3	12.3
E3s									
Mi3									
W3	Weeds	9.5-14.8 (6)	9.5-18.6 (3)	8.4-14.8 (2)	11.4-15.8 (3)	6.0-9.8 (4)	6.7-13.7 (3)	9.9	9.6
E3s		6.9-12.0 (7)	4.6-7.7 (4)	6.0-8.9 (2)	6.7-11.0 (5)	5.6-12.5 (2)	—	8.4	
Mi3		7.9-18.2 (4)	8.9-14.4 (3)	11.4-12.1 (2)	11.0-13.2 (3)	5.9-13.4 (5)	—	10.6	
W3	Mixed dried-off herbage		8.0	4.1			4.1-5.2 (3)	5.3	5.0
E3s			2.5	6.2	5.9-7.1 (2)	4.3-6.7 (2)	5.5	5.4	
Mi3			2.7-4.4 (2)	5.8-6.3 (2)		4.5-5.0 (2)	2.9-5.9 (5)	4.5	



Figs. 1, 2 & 3.—Copper content, with seasonal variations, of pasture species on three Canterbury soil types.

Fig. 4.—Copper content, with seasonal variations, of three clover species on Eyre shallow silt loam.

RESULTS

Pasture Species

Table 2 presents the copper contents of the herbage separates in terms of the range and means of recorded values—the number of

samples in each case being stated in brackets. Absence of results in certain instances may or may not mean that no sample was collected. In the case of seeded ryegrass and mixed dry herbage especially, a limited number of analyses only were performed. It will be seen that there are considerable variations both within and between species. These differences and the seasonal variations in mean levels of copper for the principal separates are illustrated in Figs. 1–4. Each point represents the mean of approximately six estimations. Wherever sufficient data were available statistical analysis has been applied to the results; and Table 3 shows the summarized analyses of variance on the whole of the data for ryegrass and white clover.

TABLE 3. Analyses of Variance on Data for Ryegrass and White Clover

	Copper Content of Ryegrass	Copper Content of White Clover
Source of Variation	F	F
Soils	25.7**	25.5**
Sampling dates	14.1**	11.2**
Soils x Dates	<1	1.47
Sampling sites within soils	6.06**	1.83

** Significant at 1% level
* Significant at 5% level

The analysis clearly shows that for both these species the amount of copper they contain differs with high significance from soil to soil, and that there is a highly significant variation between samplings—the seasonal effect. The significance of the "sites within soils" factor for ryegrass was shown to be due wholly to the results from one site.

Differences between the copper contents of the two major species, ryegrass and white clover, are analysed in Table 4.

TABLE 4. Analyses of Variance Mean Copper Content: Ryegrass v. White Clover

Source of Variation	F
Species	58.8**
Soil types	23.7**
Sampling dates	11.1**
Interactions	N.S.

Thus not only is the difference in copper content between these two species highly significant, white clover being the higher, but this significance holds for all three soil types and at all sampling dates.

Sufficient data were also available for an analysis of the variation in copper content of the three species of clover found quite generally on the Eyre silt loam. These are illustrated in Fig. 4, which emphasizes the much higher values obtained for red and subterranean clover as compared with white clover. The analysis of variance is summarized in Table 5.

TABLE 5. ANALYSES OF VARIANCE COPPER CONTENT OF THREE CLOVER SPECIES ON EYRE SILT LOAM

Source of Variation	F
Species	32.56**
Dates	34.94**
Sites	15.24**
Species x Dates	2.77*
Species x Sites	<1
Dates x Sites	<1

Differences between clover species are thus shown to be highly significant, as are the seasonal variations and the differences within the species due to the sites sampled. The significant interaction between species and sampling dates is probably a reflection of the different seasonal habits of these species.

The copper content of the separates classified as "weeds", which consisted of mixtures of flat weeds and weed grasses in varying proportions, was quite variable within sampling dates; yet in general it was found that the same trend was followed, between soils, as with ryegrass and white clover; namely, that samples from the Waimakariri soils gave the highest values, those from the Mairaki slightly lower, and from the Eyre soils lower still. The high values for some of the weed separates are due to the presence of such flat weeds as plantain (*Plantago lanceolata*), catsear (*Hypochaeris radicata*), and dandelion (*Taraxacum officinale*). For example, one separate comprising mainly plantain and catsear contained 18.6 p.p.m. copper, one of plantain and dandelion 18.2 p.p.m., while a picked sample of dandelion from the latter mixture contained 19.8 p.p.m. of copper.

Analysis of cocksfoot gave figures of 12.6 p.p.m. as the mean of four samples grown on Waimakariri silt loam, and 8.6 p.p.m. as the mean of ten samples from the Eyre silt loam. With few exceptions, the copper content of the cocksfoot was higher than that of the ryegrass from the same plot.

The other point of interest from Table 2 is the very low copper content of ryegrass at seeding and of the fraction called "mixed dried-off herbage", which consisted of dead or dried-off stems and leaves of various species not otherwise included in the separates. It will be evident from inspection of the limited number of samples analysed that the difference between leafy and mature stemmy ryegrass is highly significant.

TABLE 6. Available Copper in Three Canterbury Soil Types (p.p.m.)

Soil Type	Depth Sampled (in.)	Sites						Means
		1	2	3	4	5	6	
W3	0–2	6.0–6.4	6.0–6.4	6.0–6.4	5.6–6.0	3.6–4.0	3.6–4.0	5.3
	8–10	6.0–6.4			4.8–5.2			
	36–38	5.0–5.4			3.6–4.0			
E3s	0–2	2.4–2.8	1.6–2.0	2.8–3.2	2.4–2.8	1.6–2.0	2.0–2.4	2.3
	8–10	2.8–3.2			2.8–3.2			
	36–38	2.8–3.2			2.4–2.8			
Mi3	0–2	2.2–2.6	2.8–3.2	2.0–2.4	2.0–2.4	3.2–3.6	2.8–3.2	2.7
	8–10	2.8–3.2			2.0–2.4			
	36–38	3.6–4.0			2.4–2.8			

Soils

The available-copper contents of the initial soil samples are shown in Table 6. Each value is expressed as a range since it is felt that the method does not permit much greater accuracy than this, and each value is the mean of three assays.

From the table it can be seen that the copper contents of the topsoils follow the same trend, between soil types, as do the plant analyses, in that the Waimakariri soils are highest and the Eyre soils the lowest. The relationship between the copper contents of the soil and herbage is shown by the correlation coefficients given in Table 7.

TABLE 7. Overall Correlation Between Copper Contents of Soils and Herbage

Between copper in soil and	r
Copper in ryegrass, October 1950	0.125
Mean copper in ryegrass	0.363
Copper in white clover, October 1950	0.764**
Mean copper in white clover	0.625**

Thus for the soils under test there is a highly significant correlation between the available copper in the soil, as measured by the *Aspergillus* method, and the copper content of white clover growing on it.

Discussion

Pasture Species

The previous workers in this field, cited in the introduction, have shown consistently that the mature herbage of pasture plants contains

appreciably less copper than do the younger stages of growth; and that clovers and herbs normally contain more copper than do grasses growing in the same situation. The results of the present investigation are in full accord with these findings. Mature, stemmy ryegrass was found to be significantly lower in copper content than young leafy ryegrass, while white clover was significantly higher than ryegrass on all three soil types and on all occasions, the mean levels of copper (all soils) being 10.0 p.p.m. and 7.9 p.p.m. respectively. Red clover and subterranean clover proved higher still, their mean contents being 12.3 p.p.m. and 11.8 p.p.m. of copper respectively. The copper content of cocksfoot appears to be higher than that of ryegrass. The substantial copper content of the weeds in the pasture is an interesting point, since these will often be found in green leafy condition at times when the more valued species are in a mature and dormant state. They may thus be of special value as a source of copper at a time when it is most needed.

Seasonal Variation

The seasonal variations in copper content, already shown to be highly significant, are illustrated in Figs. 1–4. These variations are to a large degree consistent in that the variations on the Mairaki and Eyre soils are in striking agreement, both for ryegrass and white clover, while the same trend is followed by ryegrass on the Waimakariri soil, and by all three clover species on the Eyre soil. These consistent variations take on a greater significance when it is remembered that the data here reported for "ryegrass" and "white clover" are those for the green, leafy portions of the clippings, and that the variations noted are not occasioned by the comparison of green, leafy with matured stemmy herbage. It is evident that the copper content of green, leafy herbage from any of the species growing at different times on the same soil can vary considerably. There must be some common factor responsible for this large and consistent variation, and the changes in weather and growing conditions have been examined for a possible explanation. Three contrasting pairs of situations suggest that different stages and speeds of growth occasioned by weather conditions are responsible.

(1) In October 1950 the copper content of ryegrass on all three soils was low; whereas in October 1951 it was consistently high. In October 1950 the spring flush of growth was well on its way, having started towards the end of September, and by sampling time the young herbage was growing very rapidly. In 1951, however, the spring was exceptionally late, and growth of the winter-hardened ryegrass had barely begun when samples were taken.

(2) In February 1951 the copper content of ryegrass and clover was relatively high on all three soils, whereas in January 1952 the values were consistently low. The summer 1950–51 was phenomenally wet, and pasture growth was continuous and excessive to the point of embarrassment from November to March. In the summer of 1951–52 the strong growth of pastures in December rapidly matured in the hot dry weather of January; so much so that the stemmy pastures were viewed as a fire hazard.

(3) On both the Mairaki and the Eyre soils the copper content of ryegrass fell in June 1951 and rose in the following October. June 1951 was an exceptionally cold month and pasture growth had been virtually at a standstill from the end of March. Such ryegrass

as was available for sampling therefore consisted of winter-hardened short leaf. By October, however, a slow new growth had commenced. In the case of white clover the trends are confused, which may be connected with the fact that the clover will have continued its growth later into the autumn and (owing to the lateness of the spring) would not have recommenced growth by sampling time in October.

Soils and Soil-Plant Relationships

If 2.0 p.p.m. of available copper is accepted as the critical level for soils, below which the copper content of pastures growing on them may be inadequate for the needs of livestock, then it is apparent from Table 6 that the surface layer of some of the Eyre soils is deficient in copper, while others may be just able to supply sufficient copper. By the same standard the Mairaki soils may be regarded as low, but adequate, in their content of available copper; while copper may be said to be abundant in the Waimakariri soils.

Thus the order of ability of the three soil types to supply copper as rated by the *Aspergillus* test is Waimakariri > Mairaki > Eyre, with little difference between the last two. This is the same relative order as that exhibited by the copper content of the herbage separates from these soils. In Table 7 it has been shown that there is a highly significant correlation between the copper content of the soil and that of the white clover growing on it. The results, therefore, uphold the *Aspergillus* method as a satisfactory means of assessing the available copper in soils. They also provide evidence that any actual or near deficiency in the older of these soils is an acquired one. This conclusion is supported by the fact that whereas in the Waimakariri soils the available copper decreases with the depth (Table 6), in the two older soil types there is distinct evidence of copper content increasing with depth, which may be regarded as evidence of the leaching of copper.

At this point it is of interest to note that both the herbage and soil analyses place the Mairaki soils above the Eyre soils in their copper status; whereas on pedological grounds the reverse might have been expected. A possible explanation of this is that the shallowness of the light-textured A horizon of the Eyre soils, the extreme permeability of their subsoils, and the intensely dry periods to which they are subject, have all contributed to the depletion of their topsoils; whereas the Mairaki soils, though older and more weathered, have poor internal drainage, so that the retention of nutrients in their A horizons has been favoured by this and by their greater accumulation of organic matter.

From what has been said concerning the acquired copper deficiency in the older of these soils, it may be inferred that other shallow soils of the Canterbury Plains especially the older and even more strongly leached ones are probably at or near the point where copper deficiency affects the thrift of livestock. This inference is in agreement with Cunningham[32], who recently listed the Lismore and Glasnevin soils as among those growing pasture of low copper content.

Notwithstanding this dependence on soil type, differences in copper content as between species and stages of growth are so great that they constitute an over-riding factor, and suggest some interesting ways by which the practices of pasture establishment and management may be

expected to influence the amount of copper ingested by the grazing stock. The utilization of that copper by the animal, as affected by the supply of molybdenum or inorganic sulphate, or otherwise, is a different matter, not within the scope of this paper. It is clear that two factors are involved, although they are not mutually exclusive: (a) pasture composition, as affected by soil conditions, seeding, and subsequent management, (b) pasture condition, as controlled largely by grazing management. Examples of the first factor are those pastures composed largely of ryegrass with very little growth of clover that are so often obtained where there has been insufficient application of lime and/or phosphate. Lacking nitrogen, such grasses quickly run to seed, and the pasture suffers a reduction in copper content on two counts—that due to the species and that due to its stage of growth. In marked contrast are those well balanced swards of grass and clover in which the periods of maximum growth or dormancy of the different species do not all occur at the same times of the year. Such swards would appear to enjoy a twofold advantage in respect of the copper supplied to the grazing stock; firstly, in that herbage in its young stages of growth is available during a large part of the year, and secondly, in that the greater content of clovers, and possibly of such grasses as cocksfoot, will increase the average content of copper. Grazing management which maintains the bulk of the herbage in a young stage of growth, will for the same reason assure a better supply of copper to the stock than will management which allows large parts of the sward to run to maturity. Moreover, insofar as such lax grazing suppresses the growth of the clovers, there will be a further diminution in the average copper content of the herbage.

It is indeed fortunate that those methods of pasture establishment and management which are known to result in the greatest production of nutriment per acre should also appear to be the methods likely to assure the most effective use of the resources of copper in the soil.

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PHYSIOLOGIC SPECIALIZATION OF OAT CROWN-RUST (*Puccinia coronata* f. sp. *avenae*) IN NEW ZEALAND

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(Received for publication, 29 June 1956)

Summary

Thirteen physiologic races of *Puccinia coronata* f. sp. *avenae* are identified and their frequency of occurrence described.

The bearing of this work on breeding for crown-rust resistance in oats in New Zealand is discussed.

Introduction

Crown rust (*Puccinia coronata* Cda.f. sp. *avenae* Fraser et Led.) of oats (*Avena sativa* L.) was first recorded in New Zealand by Cunningham (1922). Studies on physiologic specialization in *P. coronata* f. sp. *avenae* using New Zealand uredospore collections have already been reported by Waterhouse (1952) who identified eight races using the earlier set of crown-rust differential varieties selected by Murphy (1935). The present investigation reports the identity and frequency of occurrence of crown-rust races at present identified in New Zealand, and their relative importance in the breeding of oat varieties resistant to crown-rust in this country.

Materials and Methods

Field collections of crown rust were made in the 1952–53 and 1954–55 seasons from oat crops in the major milling-oat districts of New Zealand, viz. Canterbury, Otago, and Southland. Culture purification, inoculation, and testing methods were similar to those described earlier (Cruickshank 1952). Races were identified using ten differential varieties used by Simons and Murphy (1955) viz. Anthony (C.I. No. 2143), Victoria (C.I. No. 2041), Appler (C.I. No. 1815), Bond (C.I. No. 2733), Landhafer (C.I. No. 3522), Santa Fe (C.I. No. 4519), Ukraine (C.I. No. 3259), Trispernia (C.I. No. 4009), Bondvic (C.I. No. 5401), and Saia (C.I. No. 4639). Variety reaction was based on type of infection developed on the cotyledon leaf. Resistance is equivalent to infection types '0' to '2' and susceptibility to types '3' and '4' (Simons and Murphy 1955).

The reaction of additional varieties and hybrid lines being used in oat breeding at the Crop Research Division, viz. Garry (original release, Canada), Mustang (U.S.), (Victoria x Richland x Fulghum) x Belar, Victoria x Richland x Algerian, and Winter Fulghum x (Victoria x Richland x Sunrise x Fulghum) (Australia) were also determined for each race except race 8.

Results

Race identifications are presented in Table 1. The descriptive formulae (Simons and Murphy *loc. cit.*) are given only in terms of

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TABLE 1. Race Formulae[1] of Physiologic Races of *P. coronata* f. sp. *avenae* in New Zealand

Physiologic Race No. (N.Z.)	Resistant Varieties*	Equivalent U.S. Race No.[2]
1	1 2 4 5 6 7 8 9 10	238
2	1 2 4 5 6 8 9 10	230
3	1 2 4 5 6 7 8 9	289
4	1 2 4 5 6 7 10	249
5	1 2 4 7 10	287
6	1 2 5 6 7 8 9.10	201
7	1 2 7 10	265
8[3]	1 5	—
9	2 4 5 6 7 8 9 10	237
10	2 4 5 6 7 8 9	236
11	2 4 7 10	277
12	2 4 10	286
13	2 5 6 7 8 9 10	202

1. Race formulae are represented only by appropriate resistant differential varieties.
2. Simons and Murphy 1955, Simons 1955.
3. Not tested on varieties 6, 7, 8, 9, and 10.

* Numerical key to Differential Varieties:—

1. Anthony
2. Victoria
3. Appler
4. Bond
5. Landhafer
6. Santa Fe
7. Ukraine
8. Trispernia
9. Bondvic
10. Saia

resistant varieties. In Table 2 are presented data on the frequency of occurrence of the individual races identified in 1953 and 1955.

The varieties Garry, (V. x R. x F.) x Belar, and V. x R. x Algerian were resistant to all races listed above. The variety Mustang was susceptible to all races. W. Fulg. x (V. x R. x S. x F.) was resistant to races 2, 3, 4, 7, 9, 11, 12, and 13 but gave a mixed reaction to races 1, 5, 6, and 10.

Discussion and Conclusions

Thirteen races of *P. coronata* f. sp. *avenae* have been identified in the crown-rust collections analysed in 1953 and 1955. Although these analyses represent a very small sample of crown rust in the field they do give an indication of the range of pathogenicity of races found in the major oat-growing districts of New Zealand. From Table 2 it can be seen that these races vary widely in frequency of occurrence.

TABLE 2. PHYSIOLOGIC RACES IDENTIFIED IN 1953 AND 1955

New Zealand Race No.	1952/53 Oat Crop (53 cultures)	1954/55 Oat Crop (80 cultures)
1	34.0	40.0
2	—	5.0
3	22.6	—
4	—	16.2
5	—	6.2
6	5.7	1.2
7	—	1.2
8	1.9	—
9	17.0	21.2
10	—	3.8
11	—	3.8
12	—	1.2
13	18.9	—

A comparison of the races isolated in New Zealand with those reported by Simons and Murphy (1955) and Simons (1955) showed that eleven of the races isolated are similar in terms of the varieties used to those reported by them. Direct comparisons between races identified in Australia (Baker and Upadhyaya, 1955) and in New Zealand showed that four races, N.Z. 1 (U.S. 328), N.Z. 2 (U.S. 230), N.Z. 9 (U.S. 237), and N.Z. 12 (U.S. 286) are common to both countries. One race, N.Z. 3 (U.S. 289)* is reported for the first time. Race N.Z. 8 to which both Victoria and Bond are susceptible, was identified in 1953 on an earlier set of oat differential varieties (Murphy, 1935) which included only some of the varieties in the revised set. Owing to its loss, its full identity on the present set could not be established.

No studies on the genetic basis of crown-rust resistance in relation to races identified in New Zealand have been carried out. However, a knowledge of the parentage of the varieties being used in oat breeding in this country and their reaction to the individual races identified suggests that no single gene source of resistance is available. From our present knowledge of the physiologic specialization in *P. coronata* f. sp. *avenae* in New Zealand it would at first appear that suitable breeding material with two or more genes for crown-rust resistance is available viz. Garry, (V. x R. x F.) x Belar, and V. x R. x Algerian. These sources of resistance however all contain Victoria parentage. Although Victoria blight (*Helminthosporium victoriae* M. & M.) has not been recorded in this country it is a potentially important oat disease that should be considered in the evaluation of breeding material as it attacks only the variety Victoria and selections possessing the Victoria

* U.S. Accession number supplied by Dr. M. D. Simons, Iowa, U.S.A. (pers. comm).

resistance to crown rust (Welsh, Peterson, and Machacek, 1954). On the basis of these considerations these varieties cannot be considered completely suitable as parents in a crown-rust breeding programme.

Alternative breeding schemes appear possible (see Table 1). A scheme suggested is combining the three resistances of varieties 1 (Anthony), 4 (Bond), and 7 (Ukraine). Suitable 'tester-races' for this programme are races 7, 8, and 12.

It is concluded that extensve physiologic specialization occurs in *P. coronata* f. sp. *avenae* in New Zealand as it does in other countries. Only a few of the races however are important in the breeding of oat varieties resistant to crown rust. It would appear that suitable genetic sources of resistance to crown rust are at present available for this purpose.

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